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Resource Notes-Academic Year 1993-94

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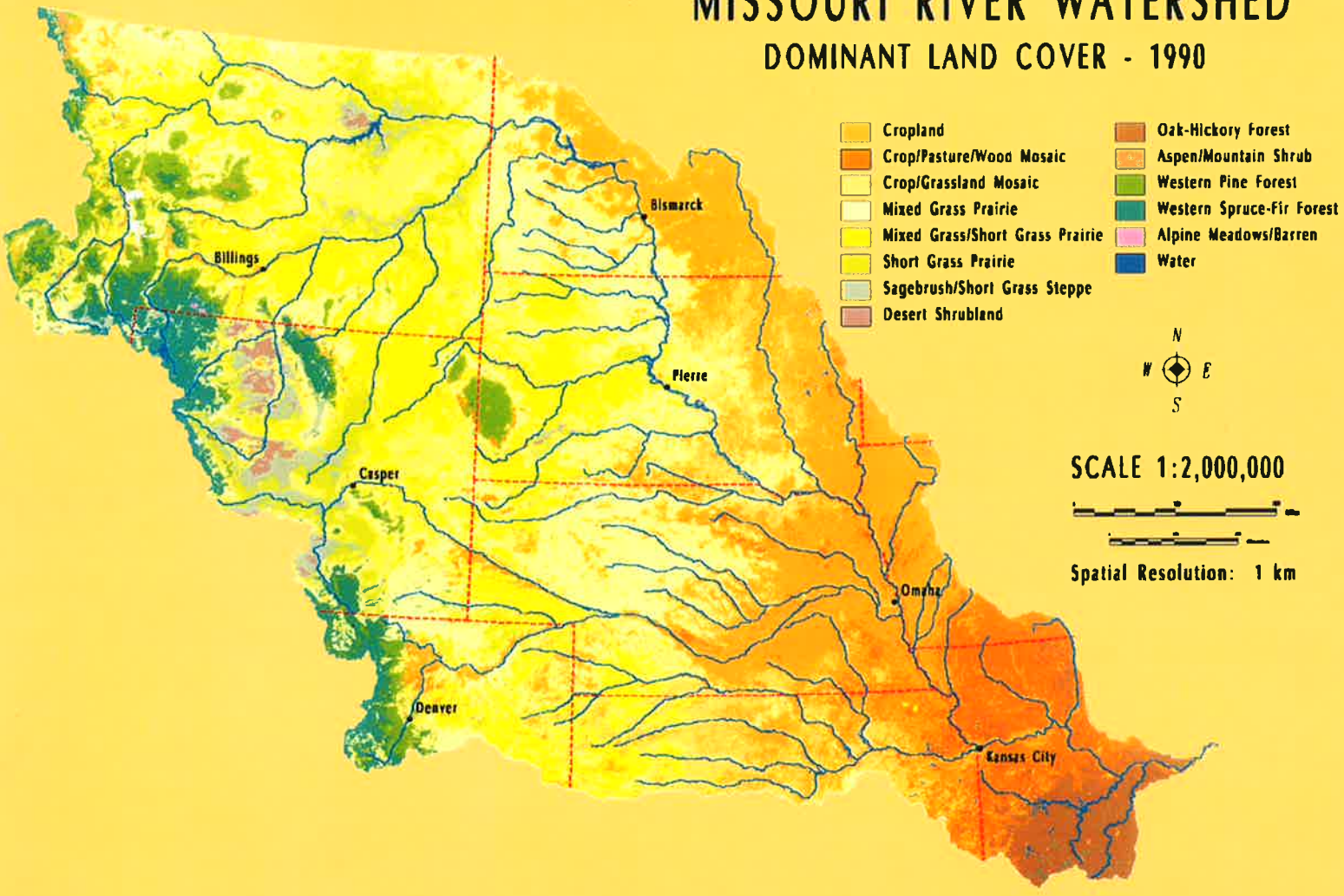


The annual news magazine of the Conservation and Survey Division

Resource Notes

Vol. VIII **Academic Year 1993-1994**

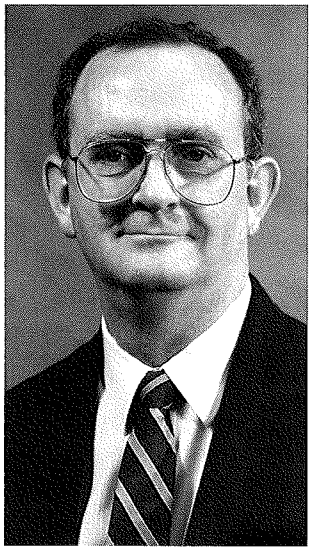
Resource Notes is an annual publication of the Conservation and Survey Division of the Institute of Agriculture and Natural Resources, 113 Nebraska Hall, University of Nebraska-Lincoln, 68588-0517. It is distributed free to all interested in earth science. To receive it, as well as the tri-quarterly newsletter, Resource News, write to the address above. The Conservation and Survey Division is the agency designated by statute to investigate and interpret the geologically related natural resources of the state, to make available to the public the results of these investigations and to assist in the development and conservation of these resources. The Conservation and Survey Division provides information and educational programs to all people without regard to race, color, national origin, sex or handicap.

Front cover: *This map portraying generalized land cover and land use in the Missouri River watershed was derived by aggregating the 159 land-cover classes contained in the U.S. land-cover characteristics data base prepared by the U.S. Geological Survey and the UNL Center for Advanced Land Management Information Technologies (CALMIT). Map courtesy of James W. Merchant, Michael S. Kelley and Jennifer B. Sharpe, CALMIT.*

Back cover: *The U.S. Geological Survey's (USGS) Earth Resources Observation Systems Data Center (EDC), working in conjunction with other data centers around the world, is preparing a unique series of global "greenness" images with a 1-kilometer resolution derived from weather-satellite data. In this example for June 1992, areas that are dark green are those exhibiting high levels of photosynthetic activity. Light green and yellow indicate lesser degrees of photosynthetic activity. Brown areas are largely barren, and white regions are covered by ice and snow. Data such as these will be used by CALMIT and EDC researchers to prepare the world's first detailed land-cover characteristics data base. Map courtesy of Jeffery Eidenshink, USGS EDC.*

From the Director:

Natural-resource data needs reach beyond state boundaries



This edition of Resource Notes reflects that we operate in a larger system than the state of Nebraska. While appropriately our focus is and will continue to be on Nebraska natural resource problems, we often must approach them in a broader, more regional context. To do otherwise would be to ignore the natural systems whose boundaries rarely coincide with political boundaries. Approaching these problems commonly requires partnerships with other states and other agencies.

The research project that resulted in a land-cover characterization of the conterminous United States is an excellent example of cooperative work between the U.S. Geological Survey (USGS) and our Center for Advanced Land Management Information Technologies (CALMIT). Results of this study will provide products that are useful on local, as well as national and global scales. The currently completed part of this study will provide baseline data for detection of global environmental change; the next phase will provide Nebraska's natural-resource managers and decision makers with land-cover data usable at an appropriate scale.

Formation of the Missouri River Basin Earth Resources Mapping Group happened because all of the states involved and the USGS recognized the need to look at certain issues on a regional or basinwide basis. This sharing of expertise results in cost savings, as well as better products. We think that many worthwhile projects will result from this association. Hopefully, these will build on the strengths of each of the surveys involved. This approach will also mesh well with the new directions of some of the federal agencies. For example, the Great Plains Initiative of the U.S. Environmental Protection Agency and the U.S. Army Corps of Engineers' Flood Plain Studies will be complementary to the work of the Missouri Basin group.

The Geological Society of America (GSA) frequently combines regional meetings to take advantage of a broader pool of expertise and to share approaches to common problems. We anticipate that the 1995 combined South-central and North-central GSA meeting in Lincoln will attract numerous papers from some of the nation's leading earth-science scholars, and we are looking forward to hosting this important meeting.

All of these activities highlight the importance of regional approaches to certain issues. Although the focus of the Conservation and Survey Division will always be the natural resources of Nebraska, sometimes, to achieve the best results, it may be necessary to expand to regional and national approaches through cooperation with other states and other agencies.

Perry Wigley, Director
Conservation and Survey Division

Missouri River basin mapping effort begun

USGS and state surveys cooperate on data-gathering

A basinwide effort to gather data on and map the natural resources of the Missouri River basin, particularly as related to earth-science issues, is being mounted by the U.S. Geological Survey (USGS) and the state geological surveys within the Missouri River basin.

"The Missouri River Basin Project is a multidisciplinary effort that focuses on the interactions between human activities and the natural systems in the basin. The State Geological Surveys in the project area and the U.S. Geological Survey have formed the Missouri River Basin Earth Resources Mapping Group to identify important regional earth-science issues within the basin, and to suggest methods and establish priorities to address those issues," according to a flyer written by William Langer of the Denver Federal Center of the USGS.

Along with Langer and USGS geologist Constance Throckmorton, state survey directors from Colorado, Iowa, Kansas, Minnesota, Missouri, Montana, Nebraska, North Dakota, South Dakota and Wyoming have joined the mapping group, as have some associate or assistant directors and selected other geologists. The University of Nebraska-Lincoln Conservation and Survey Division (CSD) has been a prime mover in setting the project in motion through the efforts of Director Perry Wigley, who collaborated early on with Langer to enlist the other state surveys in the project.

Complementary strengths

"Bill and I had two things in mind," Wigley said. "One was that some surveys are strong in some areas and not so strong in others. These strengths can be complementary. For example, Kansas is strong in petroleum, and Nebraska is strong in water. The other was the need for basinwide data bases. Even before the big floods of 1993, we saw the need for basinwide data to address flooding issues."

"We met last January, and most states agreed to form the group and create a data pool. Another consideration is that not a lot of these states are populous enough to have a lot of strength by themselves. But we can have strength as a group. And we're beginning to see the results of that strength," Wigley added.

The group had its first planning meeting at the Environmental Protection Agency's (EPA) Region VII office in Kansas City on July 26, Wigley said.

Two major types of earth-science issues affect the Missouri River basin, Langer said, those that have a direct impact on the natural system and those that have a derivative or secondary impact. Direct impacts result from human activities that are concentrated in a relatively small area, such as urbanization and mining, and occur relatively rapidly and are easy to identify. Some are natural hazards, the effects of which can be mitigated through planning. Examples of direct impacts are landslides, expansion and collapse of soils, subsidence, earthquakes and floods.

Derivative impacts have relationships to the natural system that result in changes that develop more slowly, are less easy to identify and may occur some distance from human activity. An example of these is the effect of construction of the dams on the main stem of the Missouri River, which cut the transport of sediment by the river, affecting the sediment balance in the Mississippi Delta. Derivative impacts can relate to urbanization, mining and agriculture and include soil erosion and sedimentation, contamination of surface water or groundwater, management of stormwater runoff and loss of wetlands. Flood control, navigation and irrigation systems along the river have created derivative impacts that include changes in river landscape over time, in sediment transport and deposition and in natural habitats.

The first phase of the project will focus on collection and analysis of the data, according to the USGS flyer. Regional data at scales of 1:500,000 to 1:2,500,000 are being collected for the basin. Where feasible, these data will be entered into a geographic information system. Information will be analyzed by computer and by other techniques to provide a regional perspective on the earth-science characteristics of the basin.

"Bill and I had two things in mind. One was that some surveys are strong in some areas and not so strong in others. These strengths can be complementary. For example, Kansas is strong in petroleum, and Nebraska is strong in water. The other was the need for basinwide data bases. Even before the big floods of 1993, we saw the need for basinwide data to address flooding issues."

—Wigley

Land-cover data useful on derivative impacts

Some of the regional data on derivative impacts will likely come from the land-cover and land-use characterization data base put together by CSD's Center for Advanced Land Management Information Technologies (CALMIT) (see related story in this issue). Wigley has already used a land-cover map produced by CALMIT for the basin to help "sell" the project to other state survey directors.

The regional analysis will provide the basis for identifying areas in the Missouri River basin that need more detailed study. These data will be analyzed by the Missouri River mapping group and staff for societal, environmental and geologic significance, as well as for state and local needs and human-resource needs.

For example, a subgroup is examining issues pertaining to "agro-geology," which is defined as ranging from the contribution of geologic parent materials to soil nutrients to the impact of features such as slope and topography on transport of nonpoint-source pollution.

Another more detailed look at the region involves an intensive study of the Omaha-to-Kansas City corridor, a project initiated by Wigley and Langer. This would involve intensive mapping of an area that is at least one county wide on either side of the river between the two cities and widens in urbanized areas to include Lincoln and Lancaster County in the north and Topeka to the south. This detailed mapping is intended to serve the needs of community planners, natural resources district managers, county commissioners, soil and water conservation district managers and others, Wigley said.

Wigley added that the EPA is interested in Missouri River basin mapping because of an EPA ecosystem mapping effort being mounted in cooperation with the National Biological Survey called "The Great Plains Initiative." The U.S. Army Corps of Engineers and various political officials are also interested in the project, he added.

Work on data base gains national accolades, international attention

Land-cover characteristics data base well-received by evaluators

by Charles Flowerday
Editor, CSD

A land-cover characteristics data base for the conterminous United States developed jointly by researchers at the University of Nebraska-Lincoln and the U.S. Geological Survey (USGS) EROS Data Center (EDC) has received good marks from some 20 scientists across the country who convened to evaluate its usefulness and is garnering national attention from the scientific community. The project is the first step toward creating a unique global land-cover characteristics data base that will aid research in global environmental change, assessment of biological diversity, drought monitoring and watershed management, among many other applications.

One of the products of the research, the Seasonal Land Cover Regions Map of the conterminous United States, which shows 159 "seasonally distinct" land-cover regions, has been so popular that the first printing has sold out. It is being reprinted. The complete data base is also available on CD-ROM, is compatible with most geographic information systems (GIS) and can be reconfigured to meet specific needs for land-cover information.

To complete the next phase of the project, researchers at the UNL Conservation and Survey Division's (CSD) Center for Advanced Land Management Information Technologies (CALMIT) have received a three-year, $399,000 grant from the National Aeronautics and Space Administration (NASA) to work with NASA's Earth Observing Systems on developing the world's first detailed global land-cover data base, explained Jim Merchant, associate director of CALMIT and co-director of the project with Tom Loveland, head of the Land Sciences research program at the EDC. In addition, the research has been selected as a showcase project within the USGS, and a paper on the project has received an award from a major professional society. The project has also been nominated for the prestigious Australia Prize, an award given by the government of Australia annually for achievement in an area of science and technology promoting human welfare. The 1995 prize will be given in remote sensing.

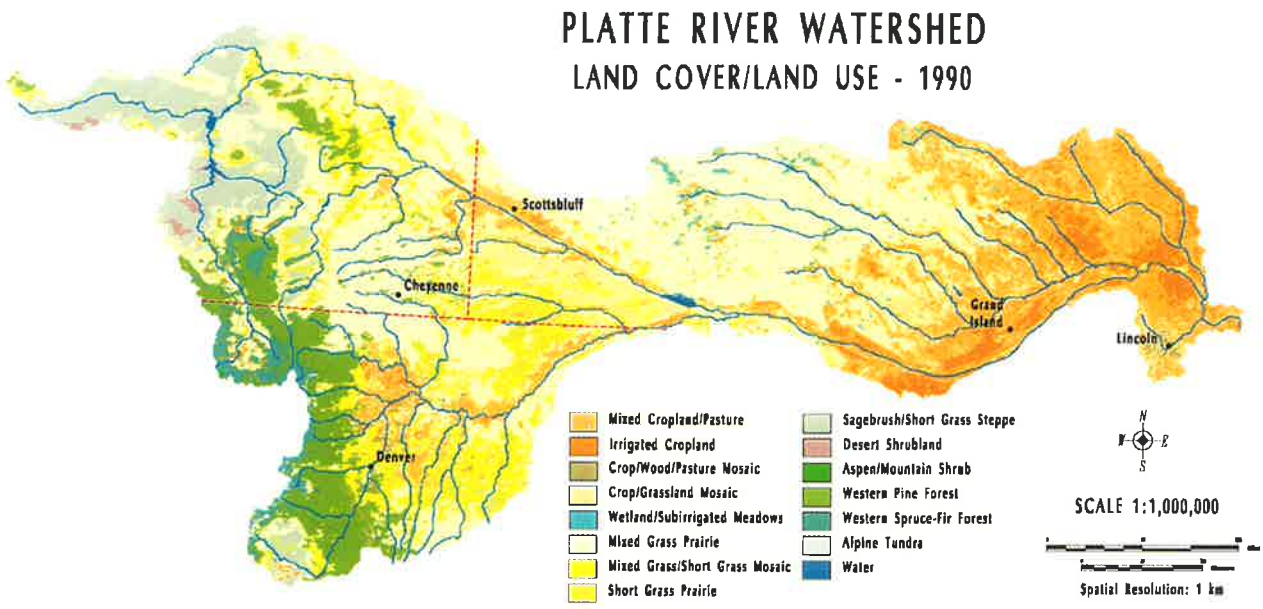
Loveland was chosen by the USGS as the Mendenhall Lecturer for 1994. The Mendenhall Research Seminar highlights the work of one USGS scientist as being outstanding in the survey. During 1994, Loveland will present the land-cover characterization project to other scientists at USGS offices throughout the country and will speak at UNL this fall.

Paper on data base wins ERDAS award

In addition, for a paper on the land-cover characteristics research, Jess Brown, formerly of CALMIT, now with the Hughes STX Corporation, Merchant, Loveland, and Brad Reed and Don Ohlen, both of Hughes STX, were the first-place recipients of the ERDAS award for best scientific paper in remote sensing. "Using Multisource Data in Global Land-Cover Characterization: Concepts, Requirements, and Methods," was published in the June 1993 issue of Photogrammetric Engineering and Remote Sensing. ERDAS is an Atlanta company specializing in image-processing software that donates money for the award, which is given by the American Society for Photogrammetry and Remote Sensing. Brown, Loveland, Reed and Ohlen all conduct research at the EDC.

One of the products of the research, the Seasonal Land Cover Regions Map of the conterminous United States, which shows 159 "seasonally distinct" land-cover regions, has been so popular that the first printing has sold out. It is being reprinted.

The land-cover research effort differs from other attempts to map land cover in that it has used the broad coverage provided by the Advanced Very High Resolution Radiometer (AVHRR), instead of finer resolution Landsat imagery, which is much more expensive and provides less frequent coverage. While AVHRR images have a resolution of about 1 kilometer—compared with about 30 meters for Landsat—they are acquired every day, in contrast to the monthly coverage of Landsat.



Because the U.S. land-cover characteristics data base is designed for maximum flexibility, products tailored to specific user needs can be readily produced. This map depicts regional land-cover patterns in the Platte River watershed. Map courtesy of Jennifer B. Sharpe, Limin Yang, and James W. Merchant, CALMIT.

By computing a "greenness" index for each 1-kilometer segment in an AVHRR image, scientists can relate photosynthetic activity to seasonal variations in moisture regimes and land cover. The rate and timing of greenness change over a growing season is an indication of the type of land cover in a given 1-kilometer area. These characteristics were first used to create 70 land-cover groupings, which were further divided into the current 159 land-cover types.

But while the NASA money ensures financial support for the duration of the project and the ERDAS award bolsters the spirits, evaluations from the immediate users of the data are the most critical to those who developed the information. With that in mind, the Office of Research of the USGS National Mapping Division (NMD) and the EDC held a three-day workshop at the EDC this spring aimed at reviewing and evaluating the U.S. land-cover characteristics data base. They plan to publish the results of the workshop in the journal "Ecological Applications."

"In spite of the fact that it's not a perfect representation of land cover, it's much better than anything that was previously available."

—Merchant

Twenty-three scientists doing atmospheric, hydrologic and ecological modeling presented firsthand accounts of their experiences using the land-cover data base to improve their modeling and research activities, according to a memo circulated by the NMD and the EDC. The group has been testing the usefulness of the data for the past two years.

"In spite of the fact that it's not a perfect representation of land cover, it's much better than anything that was previously available," Merchant explained.

Usefulness clearly demonstrated

The usefulness of the data base in meeting the needs of a wide variety of atmospheric, hydrologic and ecologic simulation models "was clearly demonstrated," the memo said. "The data base was successfully used to investigate the overall role of landscape variability within these state-of-the-art land-atmosphere interactions models," it said.

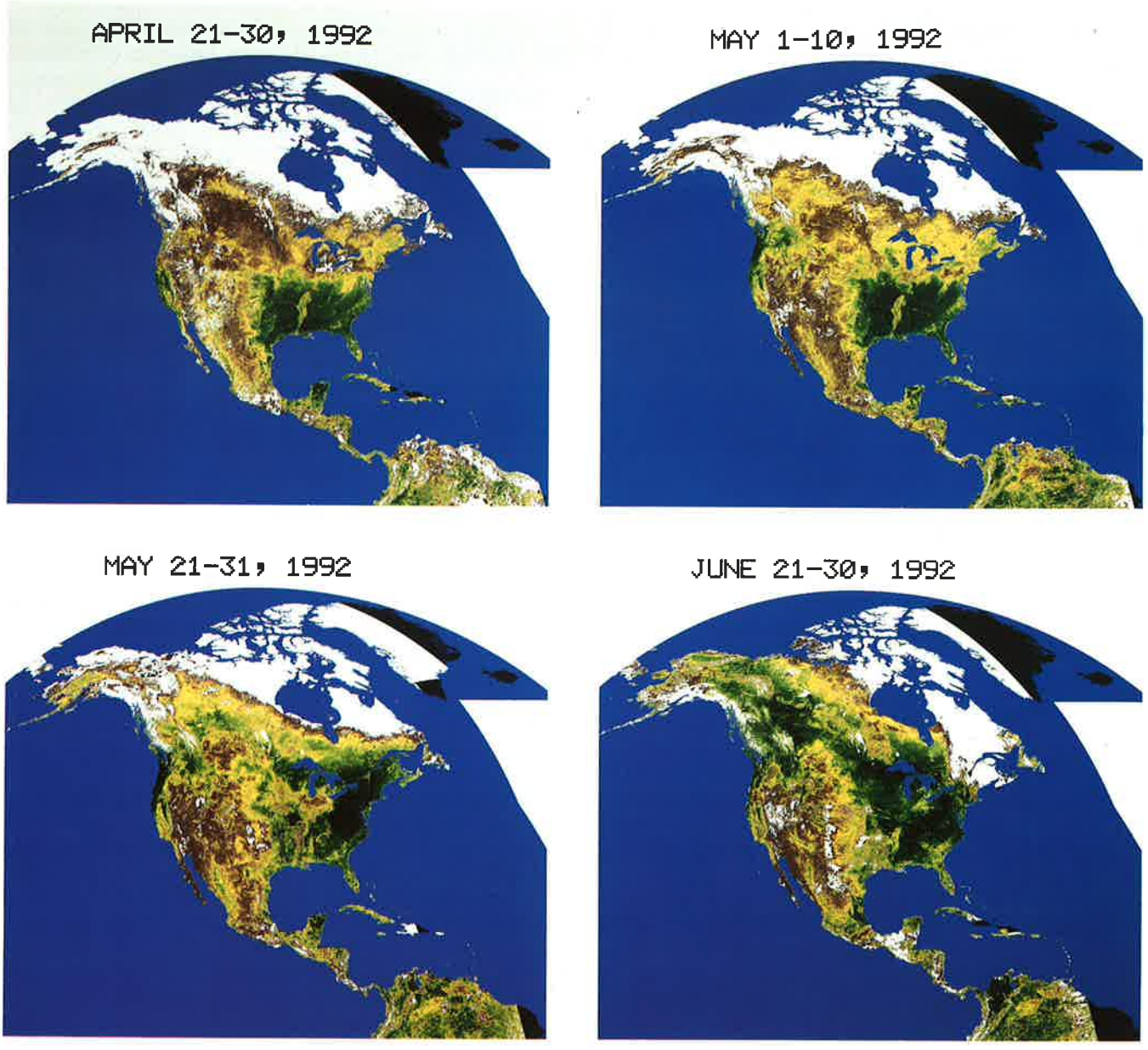
"The data base was successfully used to investigate the overall role of landscape variability within these state-of-the-art land-atmosphere interactions models."

—USGS National Mapping Division and EROS Data Center memo

"The workshop represents some of the best information on the performance of the land-cover data. It's based on the performance of their models," Merchant said. Scientists evaluating the data base were working in the areas of atmosphere modeling, surface-water quality, environmental pollution, wildfire assessment, ecosystem mapping, regional mapping of soils and biological diversity.

"We're looking at a much broader scale than ever before. That's one reason we're attracting so much interest," Merchant added.

Another important evaluation of the usefulness of the data has come through the National Water-Quality Assessment



During fall of 1994, scientists from the UNL Center for Advanced Land Management Information Technologies (CALMIT) and the U.S. Geological Survey (USGS) Earth Resources Observation Systems Data Center (EDC) will map land cover over all of North America as the first phase in developing a global land-cover characteristics data base with a 1-kilometer resolution. This effort will begin with analysis of a series of 1992 images of vegetation "greenness" derived from weather-satellite data. These images portray the manifestations in time and space of vegetative photosynthetic activity. Maps courtesy of Jeffery Eidenshink, USGS EDC.

(NAWQA) program of the USGS as it was applied to the Platte River watershed in central Nebraska. Ron Zelt, a hydrogeologist with the USGS, Brown and Mike Kelley, a CALMIT graduate student, assessed the land-cover data base by comparing the dataset to field data and concluded that, while it doesn't perform perfectly, it does perform adequately, Merchant said.

"This is important because NAWQA is a national program. If it works in (central) Nebraska, it ought to work elsewhere," he added.

Meanwhile, CALMIT and EDC researchers are working to refine the information and expand its applications.

Seasonal characteristics valuable

"One of the most valuable aspects of this data base is not just that it provides descriptions of land cover, but that the seasonal characteristics for a given year are also included," Merchant explained. "We want to improve the descriptions of seasonality of land cover, such as the onset of greenness for a particular year. Of course, that time will vary from year to year."

Working to further refine the data base are Reed and Limin Yang, a CALMIT research associate in climatology, remote sensing and GIS working at the EDC. Yang is evaluating the four main "greenness" parameters—onset, peak, duration and

total greenness—in relation to weather conditions for 1989-1993.

"Limin's background as a climatologist is particularly useful," Merchant said. Looking at climate data for the four-year period and the corresponding changes in greenness for that period, he is trying to determine a "normal" range for each of the four greenness parameters for any land-cover region.

This work is being augmented by research being done in Lincoln by CALMIT graduate student Wenli Yang, who is looking at the water-holding capacity of various Nebraska soils and their influence on land-cover characteristics.

In addition, work on the global 1-kilometer land-cover characteristics data base continues, with the preliminary map of 1992 data for North America scheduled for completion before Christmas, Merchant said. After that, South America comes next, followed by other continents, said Limin Yang, who will be working on the global dataset.

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—Merchant

"This involves hundreds and hundreds of megabytes of data. It's a huge dataset. The only agency in the world that can handle it is EROS," Yang said.

Not only are the data being used to expand land-cover assessment to the global scale, they are also being used to develop land-cover data for smaller scales.

Working on more refined land-cover data

"We recognize that what we're doing is useful at the scale of the Platte River watershed or the Missouri River watershed, but it's not that useful for natural resources districts or for counties," Merchant explained. "So we're working on more refined land-cover data for Nebraska that is based on an analysis of Landsat satellite imagery."

Currently, Merchant and Dennis Jelinski of the UNL Department of Forestry, Fisheries and Wildlife are cooperatively managing the Nebraska component of a new program of the National Biological Survey that will use geographic information systems to analyze Nebraska's critical habitat with the aim of achieving greater conservation of biological diversity. The Nebraska GAP Analysis Program will also enlist the help of a number of cooperating agencies, such as the Nebraska Game and Parks Commission, the University of Nebraska State Museum, businesses, nonprofit groups and other governmental agencies.

In general, the GAP program intends to look at the extent to which critical habitats are protected. "Gaps" are areas that are not well-protected. The program, which began this summer, will use Landsat data and aerial photography to supplement AVHRR data for work on statewide, watershed or county datasets, Merchant said.

"We can derive information about land cover from Landsat and combine it with information about seasonality from the AVHRR data," he said. "There haven't been many instances of people using the two sensors in that way."

Nebraska is one of the first Great Plains states to start gap analysis. The three-year program will eventually produce a digital data base for the state capable of generating many types of map products. The research will combine data on vegetation distribution, mapped from satellite imagery and other records, with distribution of native animal species, mapped by using state museum and other agency records, in conjunction with known habitat ranges. Maps of species-rich areas, individual species of concern and vegetation types will be overlaid on maps of land ownership and land use, showing where conservation efforts need to be targeted.

Data base used for Great Plains Initiative

Finally, the CALMIT-EDC land-cover data bases will also be used to generate information for the Great Plains Initiative, a cooperative program that began as a biodiversity initiative of the U.S. Fish and Wildlife Service and the Western Governors Association. Subsequently, the Region VII office of EPA and the Nature Conservancy became involved and offered additional money. The Region VII office has asked for help from CALMIT and the EDC in developing data bases for the Great Plains.

"We think what we've already done for the U.S. should be a help (in establishing a Great Plains data base)," Merchant said. The initiative will establish the Great Plains International Data Network, which includes Canada. It will incorporate a satellite imagery data base, a geographic information system and some socio-economic data, Limin Yang said. One of the preliminary products will be a Great Plains atlas.

Coming up: national, state and local workshops and meetings

—Annual Meeting of the Nebraska Water Conference Council, Sept. 24, 8-11 a.m., East Campus Union, UNL

—Annual Water Policy Forum for University of Nebraska faculty, Sept. 27, sponsored by Water Center/Environmental Programs.

—State Rock Show, Oct. 1-2, Nebraska Gem and Mineral Club, Omaha.

—World Food Day, Oct. 14, "Water--The Needs of Farms, Cities and Environment in Growing Conflict"; contact Sue Miller, International Programs, UNL (402) 472-2758.

—Rock Show, Oct. 15-16, Grand Island Earth Science Society, Fonner Park, Grand Island.

—Thirty-fourth Annual Midwestern Ground Water Conference, Oct. 16-18, Bismarck, N.D., Radisson Hotel, sponsored by North Dakota State Water Commission, North Dakota State Geological Survey, University of North Dakota Energy and Environment Research Center, U.S. Geological Survey-Water Resources Division, North Dakota Water Resources Research Institute; contact Robert Shaver, 900 E. Boulevard, Bismarck, 58505-0850, (701) 224-2754.

—Groundwater Foundation Annual Symposium, Oct. 18, "Drinking Water and Public Health," Ramada Hotel and Conference Center, Lincoln.

—**Nebraska GIS Forums,** Oct. 19, 1994; Nov. 16, 1994, Feb. 8, 1995, 11:30 a.m. to 1:30 p.m.; East Campus Union, University of Nebraska-Lincoln.
—**Rock Show,** Nov. 5-6, Ft. Kearney Rock Club, Hill Top Mall, Kearney.
—**Geological Society of America annual meeting,** Oct. 22-28, Seattle, Wash.

—**American Water Resources Association 30th Annual Conference,** Nov. 6-10, including the Symposium on Water Quality; Symposium on the Future Quality of the Great Lakes; the Symposium on the National Water Quality Assessment (NAWQA) program; and special sessions on GIS, Chicago, Fairmont Hotel; contact Phillip E. Greeson, U.S. Geological Survey, Norcross, Ga., (404) 409-7700.

CALMIT expands wetlands inventory to Missouri, Iowa and Kansas

Nebraska complete

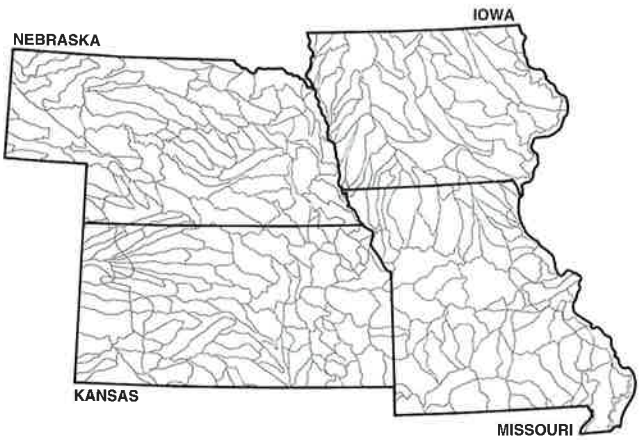
by Deborah McAdams
Editorial Assistant, CSD

A wetlands inventory that has been completed for Nebraska is being expanded to include Missouri, Iowa and Kansas, said Chris Keithley of the Center of Advanced Land Management Information Technologies (CALMIT). The four states comprise U.S. Environmental Protection Agency (EPA) region VII, or the Missouri, Iowa, Nebraska, Kansas (MINK) region. The MINK region inventory is part of an EPA effort to develop a model for evaluating wetlands degradation.

CALMIT researchers combined information from several existing data bases to complete the wetlands inventory for Nebraska. The same procedure is being used for the rest of the MINK region inventory. The EPA has provided maps--derived from ARC/INFO coverage--that divide the region into smaller ecological units.

These ecological units, referred to as Water Resources Inventory Areas (WRIAs), were established by the EPA using a combination of watershed boundaries and ecological regions.

"Vegetation, climate and biology within the units are similar," Keithley said. "The ecosystem concept was used to partition land area into homogeneous regions."



The Water Resources Inventory Areas (WRIAs) established by the U.S. Environmental Protection Agency for Missouri, Iowa, Nebraska and Kansas are ecological units that were determined from a combination of watershed boundaries and ecological regions. Vegetation, climate and biology within the units are similar. Map courtesy of CALMIT.

Several layers of information added

The WRIA boundaries represent one layer of information in the wetlands inventory, which is being compiled in ARC/INFO, the computer program that allows the visual presentation of information in single or multiple layers. Several more layers of information, also obtained from existing data bases, are being added to the wetlands inventory.

Data representing average precipitation from 1960 to 1990 have been used to create an ARC/INFO layer for average precipitation in each WRIA, according to the work plan for the project.

An ARC/INFO layer for population growth was produced using 1980 and 1990 census data at the county level. The data were converted to estimate population growth in each WRIA. A similar conversion process was applied to 1982 and 1987 Agricultural Census data. These data were used to estimate expansion of agricultural land within the WRIAs by total crop acreage.

Numbers of nesting waterfowl for the WRIAs will be estimated using information provided by The National Biological Survey, and a separate ARC/INFO layer will be created for threatened and endangered species. Additional layers will be used to display stream length and slope, length of polluted streams, hydric areas, surface runoff and land use/land cover.

The ARC/INFO data layers for average precipitation, population growth and agricultural growth are completed for the MINK region, according to the work plan. The land-use/land-cover layer has been the most time consuming because of editing needed on the source data. However, the project should be completed by December 1994, Keithley said.

Model to rank inventory areas

When the wetland inventory is complete, however, the EPA will use it to create a model for identifying the WRIAs that deserve special attention, Keithley said. The agency can then use the model to rank the WRIAs in terms of wetlands degradation in order to address the most critical areas first.

The Nebraska wetlands inventory hasn't been made available to the public yet.

"The EPA is cautious about making presumptions," Keithley said. "There is a recognizable loss of wetlands, but it's too soon to make any (more definite) conclusions."

Grad student develops data for UN's Environment Programme

Ask Jennifer Sharpe about the global village, and she'll tell you it's a reality she's prepared for, even if it's not quite here yet. Sharpe, formerly a University of Nebraska-Lincoln graduate student with the Center for Advanced Land Management Information Technologies, has moved from Lincoln, Neb., to work in Sioux Falls, S.D., to develop data on African drainage systems for the United Nations Environment Programme.

Through a U.S. Environmental Protection Agency fellowship, Sharpe is completing her graduate studies in geography at UNL by working for the UN's Global Re-

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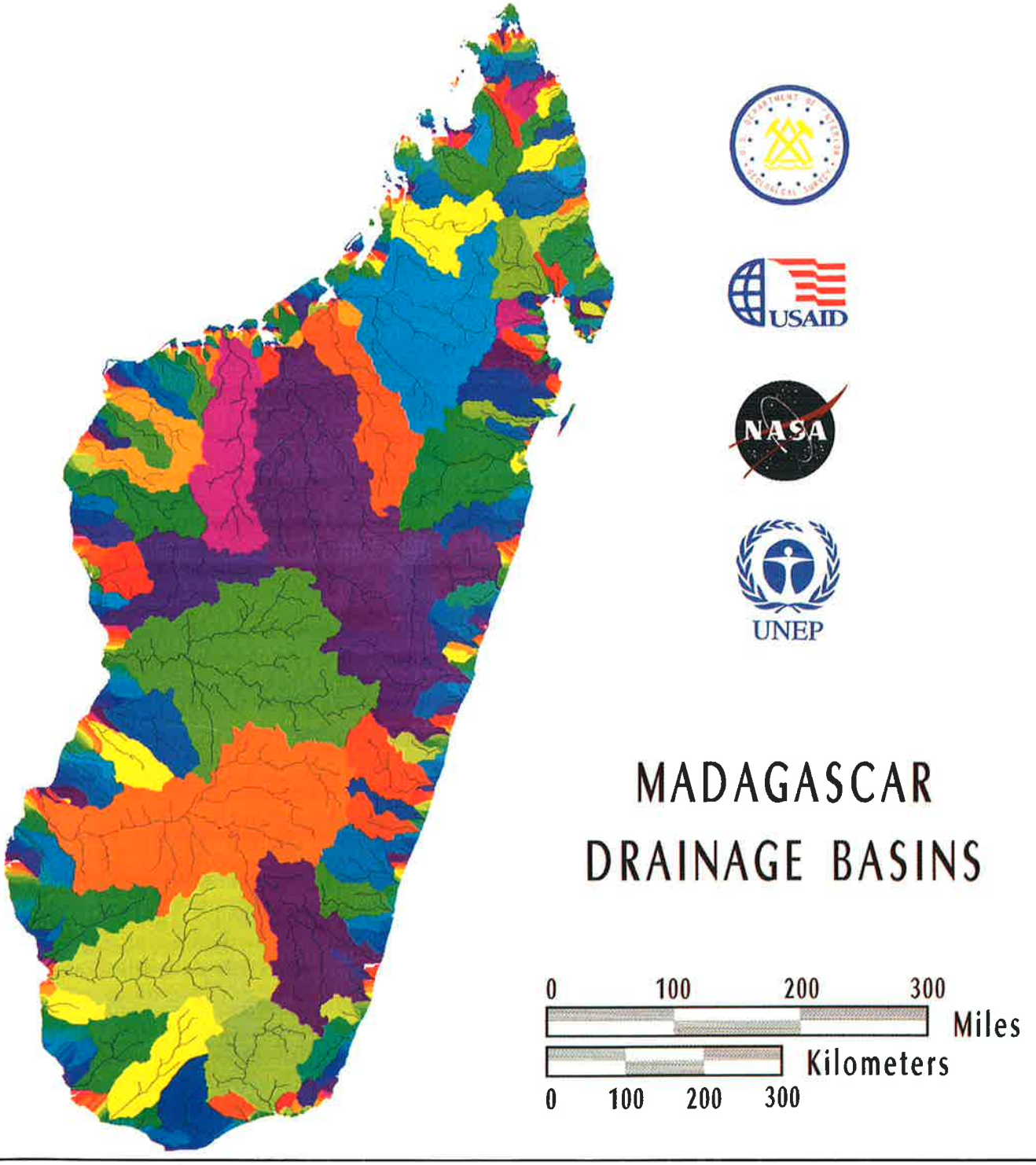


Drainage basins in Madagascar produced for the United Nations Global Resource Inventory Database. Map courtesy of Jennifer Sharpe, UN Environment Programme.

source Information Database (GRID) program at the Earth Resources Observation Systems Data Center of the U.S. Geological Survey. GRID is an international system of cooperating centers dedicated to making specific kinds of information available to international and national decision makers and environmental analysts, according to a GRID flyer. Its mission is to provide timely, reliable, geo-referenced information on the environment and access to a unique international data service to help address environmental concerns at global, regional and national levels.

Maintains a global archive

GRID maintains a global archive of environmental data accessible by computer. It ensures that the data are available in consistent, geo-referenced formats, making use of geographic information systems (GIS) and satellite image processing to allow analysts to understand where key environmental problems are occurring, as well as what they are. GRID centers are located in Tsukuba, Japan; Kathmandu, Nepal; Warsaw, Poland; Nairobi, Kenya; Bangkok, Thailand; Arendal, Norway; Geneva; and Sioux Falls, S.D. Additional centers are planned for Brazil and the South Pacific.

Examples of GRID activities include monitoring of tropical forests; global assessment of desertification; maintenance of the African Elephant data base; development of an integrated environmental data base for the entire Baltic region; and improvement of tools for managing urban areas in developing countries, among others.

Sharpe's work involves using the Digital Chart of the World, a dataset from the Environmental Systems Research Institute, to plot elevation contours and hydrology, along with other point data, to create digital elevation models, or DEMs, for selected regions, and ultimately, for the globe.

"First we look at the hydrology and make sure that the flow lines all run downhill. We put this together with the other data and then process it through ANUDEM (Australian National University Digital Elevation Model). Once that is processed, then it becomes a DEM," Sharpe explained.

Check for unnatural sinks and peaks

It is then checked for unnatural sinks and peaks and is corrected if necessary; then the final product is created, she added.

So far, Africa is complete, Sharpe said, and has been put on CD-ROM. DEMs for Canada, the United States, Mexico and Central America have been checked and are nearing completion.

Her second project spins out of the first, she said. In it, she is figuring out ways to use the 30 arc-second DEM to develop a global drainage basin dataset. The DEM will have a resolution of 30 arc-seconds. Thirty arc-seconds refers to 30 seconds, or a half minute, of a degree of latitude or longitude, which consists of 60 minutes.

She has been working on Ethiopia and the Nile River basin, checking out the DEM to make sure it works correctly and did, in fact, create the correct drainage basins. Once the DEM is complete, it will be used to create a global drainage basin dataset.

CALMIT maps used to determine investigation sites

CDC, Department of Health look at contamination due to flooding

by Deborah McAdams
Editorial Assistant, CSD

Maps usually help people see where they're going, but the Centers for Disease Control and Prevention (CDC) in Atlanta need to see where the floodwaters have gone, at least with regard to domestic wells. The CDC are looking for increased contamination of groundwater due to flooding, according to University of Nebraska-Lincoln geologist Sanford Kaplan. And the Conservation and Survey Division's Center for Advanced Land Management Information Technologies (CALMIT) is supplying the maps that help Kaplan locate the wells.

The flooding in the Midwest during 1993 was some of the worst on record.

"The CDC designed this one-time program to test groundwater in this region," Kaplan said.

Nine states are included in the region being tested: North Dakota, South Dakota, Wisconsin, Minnesota, Illinois, Iowa, Nebraska, Kansas and Missouri.

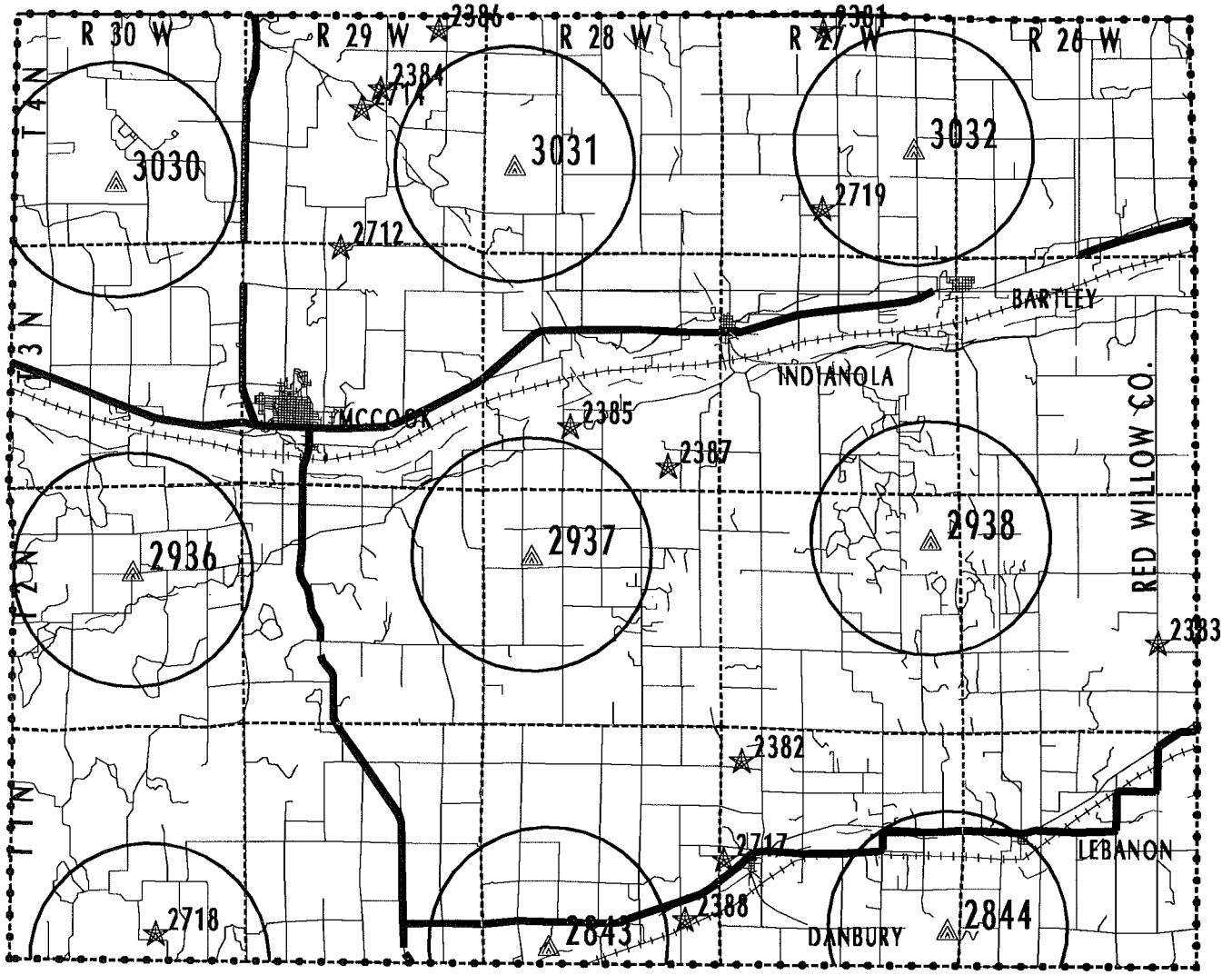
Kaplan and a crew of university students have been canvassing Nebraska, searching for domestic wells located within circles six miles in diameter on 10-mile centers as determined by the CDC. There are 1,069 such circles in Nebraska.

Maps produced by CALMIT

Maps for the project showing the circles are being produced by Fiona Renton of UNL's CALMIT. The project, administered by the Nebraska Department of Health (NDOH), also dictates that there must be a residence at the well site.

"The field people give the resident a sanitary survey form," Kaplan said. They are looking for illnesses related to E. coli, one of the contaminants being analyzed. There are always some E. coli colonies in most water, Kaplan said, so the focus of the analysis is the concentration of colonies in samples.

"The field people give the resident a sanitary survey form," Kaplan said. They are looking for illnesses related to E. coli,



Examples of the six-mile-diameter circles on 10-mile centers used by the Centers for Disease Control and Prevention (CDC) in Red Willow County to look for domestic-well contamination as a result of flooding. Map courtesy of Fiona Renton, CALMIT.

one of the contaminants being analyzed. E. coli causes flu-like symptoms and diarrhea. There are always some E. coli colonies in most water, Kaplan said, so the focus of the analysis is the concentration of colonies in samples.

Water samples are also tested for levels of nitrates and atrazine, Kaplan said. Testing for these contaminants is also included in another study funded by the CDC but limited to Nebraska. The same maps being used by Kaplan's group are

being used by the NDOH in a survey of 2,400 Nebraska wells that aren't necessarily located in the CDC sample-circle areas.

This study was first conducted in 1985-1986, and samples were tested for total coliform, nitrates, fluoride and pesticides. Results from both projects will go back to the CDC and the NDOH, where the data can be retrieved on ARC/INFO, a geographic information system.

The results of the study of wells within the 1,069 CDC circles will also be sent to the homeowners, he said.

"The state can't compel an individual homeowner to remediate a site, but they can recommend the services of a environmental health scientist from NDOH. And sometimes it's as simple as chlorinating the water," Kaplan said.

Japanese Public Television visits CALMIT to learn about food supply

A production crew for Japanese public television visited the Conservation and Survey Division in July to gather information about irrigation in Nebraska. Director Yuko Matsuda said they were making a documentary about food production.

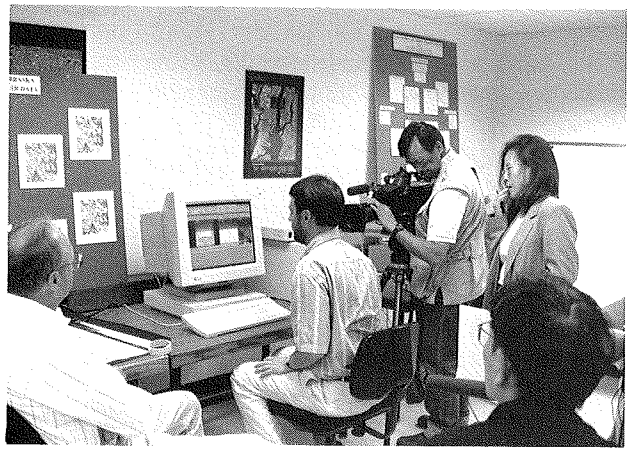
"We started looking at the food supply and what is involved in farming," she said.

Producer Kazuta Hioki was particularly interested in the development of center-pivot irrigation systems. Chris Keithley of the Center for Advanced Land Management Information Technologies (CALMIT) provided two satellite images of Box Butte County illustrating the increase in pivot systems between 1974 and 1991. Don Rundquist, director of CALMIT, also provided the crew with a report on the history of center-pivot development in the state.

Matsuda said there was another production crew doing similar research in Eastern Europe.

"One aspect (of the documentary) is a comparison of the U.S. and the former Soviet Union in grain production," she said.

Ultimately, the film will offer analysis of the world food supply into the next century, she said.



CALMIT staff and members of a production crew from Japanese Public Television examine geographic information system images of irrigation in Nebraska during the filming of a special on world food production. Photo by Deborah McAdams, CSD.

GIS for Nebraska archeology one of the first in the nation

Program will help plan development around important sites

By Deborah McAdams
Editorial Assistant, CSD

Nebraska may soon have one of the first archeological geographic information systems (GIS) in the United States, said Christopher Dore of the University of Nebraska State Museum. The system will provide a visual, layered computer record of the state's archeological cultural resources. The program will be particularly useful for planning road construction that could unearth archeological sites.

Dore, along with LuAnn Wandsnider of the UNL anthropology department, are coordinators for the project, which was recently funded by a grant from the Transportation Enhancement Program of the Intermodal Surface Transportation and Efficiency Act and administered by the Nebraska Department of Roads.

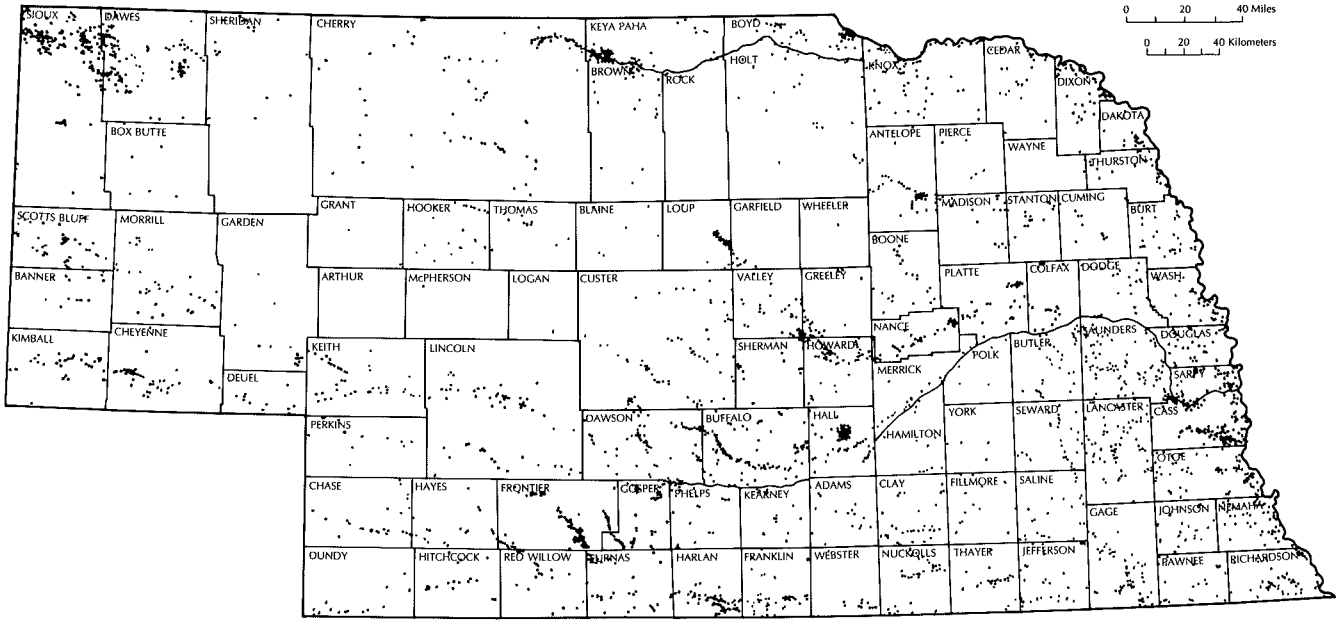
"We'll start with existing records from the Nebraska State Historical Society," Dore said.

Those records include the locations of approximately 5,500 locations related to prehistoric and historic archeological sites, the vast majority of which are Native American, he said. The sites range from single projectile points to entire villages. The

"In 1910, they may have been pacing things off to describe a location. Archeological standards have changed."

—Dore

Historical Society records list a point-location for each site. The point-locations will be used to create the base layer of the archeological GIS.



Reported Archeological Sites in Nebraska.

Accuracy of point-locations unknown

The accuracy of the point-locations is unknown since Nebraska's archeological records have been collected at various times with varying standards of accuracy throughout the last century.

"In 1910, they may have been pacing things off to describe a location," Dore said. "Archeological standards have changed."

Consequently, a second, more detailed GIS layer will be created for transportation corridors scheduled for development over the next decade, such as Highway 2 and the Heartland Express. Information about sites in this high-priority area will be categorized by reporting date and by archeological-site type. The reporting dates will help researchers assess the accuracy of the information.

Ultimately, the archeological GIS will be incorporated into a Pilot Cultural Resources GIS. The pilot program will combine different types of GIS information from several state and federal agencies.

"The reports from the last 20 years are better," Dore said.

Categorizing site type is important because the area of each site varies from the size of an arrowhead to that of an earthlodge village. The existing point-locations contain no information about site boundaries, which will be determined using survey and excavation reports and verified by a field crew using Global Positioning System technology, a computerized means of establishing a location with exceptional accuracy.

The high-priority area GIS layer will help researchers estimate the time and effort necessary to develop the base GIS layer to the same level of detail as the high-priority layer. The high-priority layer will also be used to establish the accuracy of the base layer. This distance will determine the perimeter of an archeological-site area that must be searched before it can be developed.

Pilot Cultural Resources GIS to be developed

Ultimately, the archeological GIS will be incorporated into a Pilot Cultural Resources GIS. The pilot program will combine different types of GIS information from several state and federal agencies.

Separate GIS layers pertaining to rivers and streams, topography, soil types and land use will probably be obtained from the U.S. Geological Survey.

A road network GIS layer will be provided through highway base maps and road maps obtained from the Department of Roads or the UNL Conservation and Survey Division's Center for Advanced Land Management Information Technologies (CALMIT).

A GIS layer from CALMIT's Seasonal Land Cover Regions data base will also be included to show land use and land cover.

The Pilot Cultural Resources GIS will be developed in TNTmips and ARC-INFO software, common programs for geographic information systems.

The archeological GIS will protect Nebraska's ancient history in several ways. Besides road construction, many archeological sites are compromised by the growth and development of communities, especially those near Interstate 80. The archeological GIS will help planners identify potential threats to these sites and to develop alternative growth patterns for communities.

In addition, erosion damage to archeological sites on reservoirs near the middle Missouri River has been observed and documented. This information, applied through the archeological GIS, could help officials evaluate possible damage to sites near other Nebraska reservoirs.

The archeological GIS also will be used by researchers studying prehistoric land use.

New Mead site is larger and better located

CALMIT acquires new research site with expanded capabilities

The Center for Advanced Land Management Information Technologies (CALMIT) of the University of Nebraska-Lincoln has recently established a new research site with expanded capabilities that enhance research in close-range remote sensing of surface-water quality and wetland vegetation. The new site at the University of Nebraska Agricultural Research and Development Center at Mead replaces another, smaller and less strategically located Mead field lab site, according to Don Rundquist, director of CALMIT, a program of the UNL Conservation and Survey Division (CSD).

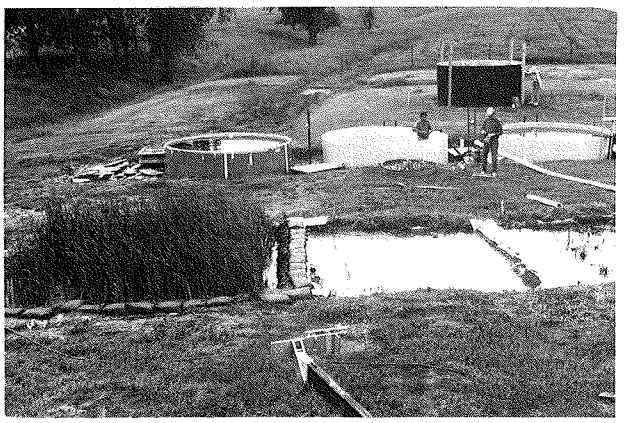
The new site is situated near the CSD warehouse, allowing for convenient storage of CALMIT's field equipment. Excavations for water tanks have allowed for four 2,500-gallon tanks and one 5,600-gallon tank—essentially backyard "swimming pools"—that are used in water-quality research, Rundquist said. The water-quality research has involved studies of the spectral qualities of varying turbidity levels, of algal chlorophyll and of submerged targets under different turbidity conditions.

Another feature of the new site are plots with controlled drainage and water delivery that allow for growing pure stands of specific wetland vegetation. About a dozen plots are used for doing basic research on specific wetland species. Reeds, wild rice, cattails, bulrushes and other species are analyzed for change in spectral properties through the growing season and as water levels fluctuate, Rundquist added. This basic research is related to research on Sand Hills lakes and wetlands that looks at the responses of wetland systems as indicators of environmental change.

Species identification and biomass assessment

Species identification and biomass measurements are important in assessment of trace gases. Methane from decomposing biomass and carbon dioxide production differ depending on the species, and both gases contribute to global environmental change. The methane released is regulated by the water level, Rundquist said. Another application of the basic work done at Mead involves incorporating a radar measurement that may allow researchers to see through the vegetation canopy to the water beneath it.

Another addition to CALMIT's research capabilities is a 20-foot pontoon boat with a telescoping boom that supports sensors and cameras. The research vessel is used in close-range remote sensing and water-quality monitoring of lakes and reservoirs.



At the new research site for the UNL Center for Advanced Land Management Information Technologies (CALMIT), plots with controlled drainage and water delivery allow for growing specific stands of wetland vegetation (in front), and excavations for water tanks (in rear) make possible water-quality research that has examined the spectral qualities of varying turbidity levels, of algal chlorophyll and of submerged targets under different turbidity conditions. CALMIT photo.

New publications from Conservation and Survey

—Taxonomy, Paleoecology and Biostratigraphy of the Crinoids of the South Bend Limestone (Late Pennsylvanian-Missourian ? Virgilian) in Southeastern Nebraska and Southeastern Kansas: R.K. Pabian and H.L. Strimple (PP-1) - $6.50

This is the premiere paper in the Conservation and Survey Division's new Professional Papers series. The 55-page paper is the culmination of 15 years of work on the South Bend Limestone in southeastern Nebraska and southeastern Kansas. The paper gives a detailed look at the stratigraphy and types of crinoids present in the rock unit and, based on correlations between Nebraska and Kansas sites, suggests renaming several facies of the unit. Most significantly, it suggests revising the boundary between the Missourian and Virgilian ages in the Nebraska section of the South Bend Limestone. The paper offers a new look at some possible solutions for placing geologic time-unit boundaries.

—Geology, Geologic Time and Nebraska: M.P. Carlson (EC-10) - $5.50

This geological primer is intended for junior high and high school students and other general-audience readers. The 59-page educational circular was the outgrowth of a talk given countless times to countless audiences, according to its author. The richly illustrated volume serves as an easy introduction to geology and geological processes, especially as they relate to Nebraska.

"If there's anything we want to convey, it's the immensity of geologic time," Carlson said. To that end, the primer begins with an overview of geology and geologic time, using common analogies to illustrate these abstract principles. The primer also includes a section on plate tectonics, revealing the reasons behind the formation of mountains, volcanoes and earthquakes.

—Groundwater-level Changes in Nebraska, 1992: G.V. Steele and P.B. Wigley (WSP-72) $3.50

The area affected by groundwater declines decreased in the three groundwater control areas in Nebraska during 1992, compared with the decline acreage for the same areas during 1991. The decreases in the acreage of groundwater-level declines came in the Upper Big Blue, Lower Big Blue and Upper Republican groundwater control areas. These comparisons come from the 39th annual report on the state's groundwater levels published by the Conservation and Survey Division of the University of Nebraska-Lincoln.

This report represents a scaled-back version of previous years' reports. The report focuses on the areas with the greatest changes: the Upper Big Blue and Little Blue groundwater control areas, the Upper Republican groundwater control area and Box Butte County, as well as the rise area in the central part of the state.

—Geologic Framework of the Niobrara River Drainage Basin and Adjacent Areas in South Dakota Generally East of the 100th Meridian West Longitude and West of the Missouri River: R.F. Diffendal, Jr. and M.R. Voorhies (GSI-9) $3

In this Report of Investigations, general geology and stratigraphy of the Niobrara River drainage basin in Nebraska and adjacent parts of South Dakota generally west of the Missouri River are examined. Of particular importance are the correlation of the Long Pine Formation of Pliocene age in Nebraska with the Herrick Gravels in South Dakota, the recognition of the members of the Ogallala Group named by Skinner, Skinner and Gooris and by Skinner and Johnson, and the recognition of the Rosebud Formation of the Arikaree Group in the basin. Rocks now included in the Rosebud were placed previously in the White River Group by the Conservation and Survey Division. A refined geologic map of the area shows the currently known distributions of all the major units, including the Long Pine/Herrick, the Rosebud and the Chadron formations, none of which has been shown on a map of the study area previously.

—Nebraska Mineral Operations Review, 1993: R.R. Burchett and D.A. Eversoll (MP-36) $2

Increased production of all minerals except clay and oil helped keep the total value of Nebraska's minerals near the $200 million level. Total value of mineral production dropped from $214.2 million in 1992 to $197.2 million in 1993. The value of non-fuel minerals and uranium rose from $115.2 million in 1992 to $120.7 million in 1993. That increase helped maintain the trends of rising values in non-fuel mineral production. The majority of non-fuel minerals peaked in 1981 at about $316 million and declined from then until 1989, when they again began to rise for a two-year period and declined again. The value of oil and gas decreased from $99.5 million in 1992 to $76.5 million in 1992.

This annual report details nearly all aspects of mineral industry production in Nebraska during 1993. The 15-page publication includes maps depicting the locations of quarries, pits and mines that were active last year and two tables, one summarizing mining activity by county from 1990 and the other detailing production by county in 1993. Information from the natural gas, oil, clay, limestone, sand and gravel industries and other mineral-resource industries is also reported.

—Fundamentals of Groundwater Contamination: Darryll T. Pederson (EC-11) $4.50

The difficulties of groundwater remediation, or clean-up, are outlined in this publication. Prevention is the best medicine for groundwater contamination. Two main variables--geology and the nature of the contaminant--influence the behavior of contaminated groundwater. For example, some water-soluble contaminants move at the same velocity as the groundwater, while a contaminant that is denser than water will sink through the saturated zone and pond on the underlying rock. Gasoline, which is less dense than water, will float to the top of the water table. The viscosity of a contaminant may determine how fast it moves through the surrounding geologic material.

Geology is a primary determinant of the speed and direction of groundwater flow. Consequently, geologic materials affect contaminant movement. Contaminants may remain suspended in clay and silt longer than in sand and gravel. Some contaminants may bond to clay particles that have unbalanced electrical charges. While Nebraska's geology differs throughout the state, contaminants are able to reach the groundwater in most areas.

—Banded Agates—Origins and Inclusions: Roger K. Pabian (EC-12) Price to be arranged

Examination of numerous agate nodules and their stratigraphic settings shows that agates are confined to only five lithologies. Examples are: 1) rhyolitic ash-flow tuffs, Jefferson County, Oregon; 2) tholeitic basalts, Brewster County, Texas; 3) andesites, Estacion Moctezuma, Chihuahua, Mexico; 4) regressive marine carbonates, Platte County, Wyoming; and 5) continental claystones, Sioux County, Nebraska.

Silica sources for thunder eggs in ash-flow tuffs were probably secondary products from glass devitrification and dissolution. In young geologic settings when unaltered ash-flow tuffs and/or ashes overlie basalts and andesites, the basalts and andesites contain no agates. In geologically older rocks, the tuffs and ashes are altered to clays, zeolites, and silica gels. Tuffs and ashes are often absent in very old rocks, and the underlying basalts and/or andesites are agate bearing.

Agates are sedimentary diagenetic products whose occurrence is related to saline-alkaline conditions, arid climates, paleosols, and unconformities. The terms chert, thunder eggs and agates should not be used interchangeably, as each represents a unique geochemical setting.

—Clay County Test Hole Log Book (THR-18): $4
—Cass County Test Hole Log Book (THR-13): $8.50

New maps

—Native Vegetation of Nebraska: Robert B. Kaul and Steven R. Rolfsmeier; color print with text (1:1,000,000 scale) (GIM-54) - $3.50

This map represents an updated, more detailed version of a popular map of Nebraska's presettlement vegetation. The popular 1975 map, "Vegetation in Nebraska, circa 1850," has been renamed for the updated version. Its new title emphasizes the native landscape being depicted. The new map is much more detailed than the 1975 map. The number of vegetation categories has increased from 13 to 16, and the explanatory text for each category has been greatly expanded.

—**Seasonal Land Cover Regions of the Conterminous United States:** U.S. Geological Survey EROS Data Center (1:7,500,000;1993) - $4.00 (LUM-32)

—**The World Map** (1:30,000,000): U.S. Department of Defense (GIM-68) $5
—**The United States** (1:4,560,000): The National Geographic Society (GIM-69) $10
—**The United States Shaded Relief** (1:7,500,000): U.S. Geological Survey (GIM-70) $3
—**The United States by Satellite View** (26" x 16-3/4"): U.S. Geological Survey (GIM-71) $3
—**Landforms of Conterminous United States--A Digital Relief Portrayal** (1:3,500,000): U.S. Geological Survey (GIM-72) $5
—**U.S. Congressional Territory Map** (1:3,168,000): U.S. Geological Survey (GIM-73) $5
—**Indian Tribes Map** (19" x 28"): U.S. Geological Survey (GIM-74) $3
—**Map of Emerging Nation** (29" x 22"): U.S. Geological Survey (GIM-75) $3

Nebraska Geonotes

Geonotes is a series of non-technical informative booklets containing information on the mineral resources and geology of Nebraska. The booklets offer valuable information to those involved in mineral-resource exploration and serve as good teaching tools at both primary and secondary levels. Each booklet also contains a list of references as a source for further investigation.

—**Earthquakes in Nebraska (revised):** R.R. Burchett (GIM-23) $.50
—**Oil and gas facts for Nebraska (revised):** R.R. Burchett (GIM-47) $.50
—**Mineral facts for Nebraska (revised):** R.R. Burchett (GIM-38) $.50

Please use order numbers (in parentheses) and add $1.50 for shipping and handling. Nebraska residents should add city and state sales tax.

GSA regional meeting in Lincoln in spring of 1995

North-central and South-central sections to be held jointly

It has been 23 years since the last regional meeting of the Geological Society of America (GSA) was held in Nebraska. And in the interests of highlighting the large strides made in geological research in this part of the Great Plains, geological organizations in Nebraska and Kansas have volunteered to sponsor the first regional section meeting since 1971.

The North-central and South-central sections of GSA will meet April 27 and 28, 1995, at the Nebraska Center for Continuing Education in Lincoln and at the East Campus Union of the University of Nebraska-Lincoln. The meeting will be hosted by the UNL Conservation and Survey Division (Nebraska Geological Survey); the UNL Department of Geology; the University of Nebraska State Museum; the Department of Geography and Geology at the University of Nebraska at Omaha; the Nebraska Geological Society; the Omaha office of Woodward-Clyde Consultants; and the Department of Geology at Kansas State University, according to the preliminary announcement and call for papers.

The North-central section includes Ohio, Michigan, Indiana, Wisconsin, Illinois, Minnesota, Iowa, Missouri and Nebraska, as well as western Ontario and Manitoba. The South-central section includes Kansas, Oklahoma, Arkansas and Texas.

Other societies meeting in conjunction with GSA

Societies that will meet in conjunction with the combined section meeting include the Pander Society; the North-central and South-central sections of the Paleontological Society; the Texas, Midcontinent and North-central sections of the National Association of Geology Teachers; and the Great Lakes and Midcontinent sections of the Society of Economic Paleontologists and Mineralogists.

"We haven't had a meeting of the regional section of GSA in Nebraska for many years," said Bob Diffendal, research geologist with the Conservation and Survey Division (CSD) and general chair of the section.

Since then, Diffendal said, important new work has been done in reclassifying the Pleistocene in eastern Nebraska, in determining the chronology and sedimentology of the Nebraska Sand Hills, in refining the geologic history of western

"We haven't had a meeting of the regional section of GSA in Nebraska for many years."
—Diffendal

Nebraska, in studying and reclassifying loess deposits in Nebraska, in dating of the Holocene valley fills in Nebraska, on the Ashfall Fossil Beds site in north-central Nebraska and on the environmental conditions during formation of ancient soils in the Cenozoic, Cretaceous, Pennsylvanian and Permian deposits, to name a few areas.

Some of these areas of study will be represented in symposia or in pre- or post-meeting field trips. Symposia slated for the meeting are: "Cyclic Sedimentation in Carboniferous and Permian Strata of North America: Sequence Stratigraphy, Biostratigraphy and Paleoecology," by Darwin Boardman II and Arthur Cleaves; "Geoarcheological Research in Fluvial and Eolian Depositional Environments," by Rolfe Mandel; "Quaternary Eolian Deposits of the Midcontinent: Loess, Sand

and Ash," by E. Arthur Bettis III, James Swinehart and Brian Carter; "Remote Sensing and GIS for Water-quality Assessment," by Donald Rundquist; "Perspectives on Urban Geology: Principles, Educational Needs and Case Studies," by Perry Wigley and Priscilla Grew; "College-related Earth Science Activities for K-12 Schools," by Bob Pinker and David Gosselin; "Ogallala Group and Younger Neogene Geology," by R.F. Diffendal, Jr.; "Chemical Dispersions in Hydrologic Systems," by Sambhud Chaundhuri; "Geology of the Garbage Heap," by Sanford Kaplan and Page C. Twiss; "Modern and Ancient Lake Environments of the Northern Great Plains," by David Gosselin and William Last; "Antarctic Paleoclimates and Paleoenvironments," by Bob Harwood; "Occurrence, Transport and Transformation of Pesticides and Nutrients in Surface and Ground Waters," by Mary E. Spalding; "Great Plains Neogene Tectonism," by George Shurr; "Catastrophic Floods," by John Shroder and Kevin Cornwell; "Environmental Regulations and the Regulated Community: Impacts and Responses," by Hugh Stirts; "Genesis and Morphology of Paleosols," by Mark Kuzila; and "Cretaceous Rocks of the Midcontinent," by David Watkins and Richard Hammond. Greg Brown of the NU State Museum will also offer a short course on "Field and Laboratory Techniques for Vertebrate Fossils."

Pre-meeting field trips

Pre-meeting field trips are as follows: "Pennsylvanian and Permian Strata of Southeastern Nebraska," by Roger Pabian; "Sandhills, Loess and Holocene Alluvial Fills," by James Swinehart, David Loope and David May; and "Quaternary Geology of Eastern Nebraska," by William Wayne. Post-meeting field trips are: "Geology of Ashfall Fossil Beds State Park and Adjacent Areas," by Michael Voorhies; "Geology of the Ogallala/High Plains Regional Aquifer System in Nebraska," by R.F. Diffendal, Jr.; "Late Quaternary Landscape Evolution in Eastern Nebraska," by Rolfe Mandel and E. Arthur Bettis III; "Environmental Geology of Douglas and Sarpy Counties (Omaha)," by Robert Goodwin; "Upper Pennsylvanian Paleosols, Lower Platte and Weeping Water Valleys, Southeastern Nebraska," by R.M. Joeckel; "Permian Strata in the Manhattan, Kansas, Area: Implications for Climatic and Eustatic Controls," by Allen W. Archer, Page C. Twiss and R.R. West; and "Cretaceous Geology of Northeast Nebraska and Southeast South Dakota," by Raymond R. Anderson.

In addition to contributing to the education of academic and private-sector geologists, the meeting organizers plan to offer a special symposium for college and university teachers on geologically related educational activities and a forum on K-12 education. While still in the planning stages, it is expected that university credit can be granted through the University of Nebraska Division for Continuing Studies to K-12 teachers who participate in a post-meeting field trip and write a paper on how to incorporate field-trip learning into the classroom.

"Giving credit to teachers who go on the field trips is something that's not been done at our regional meeting before," Diffendal said.

Preregistration by mail will be handled by the GSA Meetings Department, P.O. Box 9140, Boulder, Colo., 80301-9140. Preregistration fees will be $45 for professional GSA members or members of associated societies taking part in the meeting and $15 for GSA student members. For those not affiliated with GSA or the associated societies, preregistration will be $50 for professionals, $20 for students and $10 for K-12 teachers. The preregistration deadline is March 24. On-site registration will cost $10 more for professionals and students. For further information, contact Bob Diffendal at CSD, (402) 472-7546.

"Giving credit to teachers who go on the field trips is something that's not been done at our regional meeting before."

—Diffendal

Geologists look to sand layers in fens to determine ancient climate

Peat in sand yields clues to climate change

by Deborah McAdams
Editorial Assistant, CSD

Peatlands known as "fens" that have been discovered in Cherry County could reveal evidence of dramatic shifts in climate during the last 13,000 years, according to two University of Nebraska-Lincoln geologists. Jim Swinehart, research geologist with the UNL Conservation and Survey Division (CSD), said the peat contains layers of sand that were probably deposited by wind during extended periods of drought.

Prior to discovering sand in the fens, geologists from UNL had been trying to establish a record of Sand Hills dune activity over the last 10,000 years.

"We were trying to see inside of dunes, searching for ancient soils, so we were looking at blowouts and river cuts," Swinehart said. "Most of the stuff we saw was usually less than 3,000 years old. The old soils that formed when the dunes were inactive and stabilized are often cannibalized. As the dunes migrate, the old soils get recycled into the moving dune."

Radiocarbon dating indicated that the material was very young geologically. In some river cuts, Swinehart and David Loope, a UNL geology professor, found 3,000 to 8,000-year-old material underneath dune sand. However, critics have said that these ages do not necessarily indicate when the big dunes formed because the sand could have shifted just a few hundred feet sometime in the last 8,000 years.

Needed to see center of dunes

"We needed to see the center of dunes, so we drilled cores farther into the dunes," he said. "Only four out of 13 times we

found datable material, and that was 10,000 to 13,000 years old. We already knew the dunes had moved since then, but we needed a more complete record."

While the geologists were taking cores of sand dunes, Chuck Markley, a CSD soil scientist working out of Valentine, was doing soil-survey field work in Cherry County. Markley and other soil scientists found several areas where there were significant thicknesses of peat, or Cutcomb soils. One of the fens measured six feet in depth with a layer of sand beneath it. The bottom of the peat was found to be about 4,000 years old.

Markley later called Swinehart and told him that he was finding layers of sand in the upper part of the peat out in flat meadow areas, far from any rivers. Markley also found that the sand deposits were thinner on the southern edges, indicating possible deposition by northerly, winter winds, a direction of deposition common to moving dunes in the Sand Hills.

During the summer of 1993, Swinehart, Loope and a crew went to core in Cherry County and found several definite layers of sand in peat that was eight feet thick.

Grad student selects six sites with sand

Michael Ponte, a UNL graduate student in geology, later returned to Cherry County and selected six sites where he found multiple layers of sand. He and Markley used shovels and augers to see how areally extensive the upper layer of sand was in the peat.

"Mike went to Jumbo Valley just north of Hyannis and found 11 feet of peat in one core without finding the bottom," Swinehart said. "The core contained a layer of sand at three feet that dated at 960 years ago."

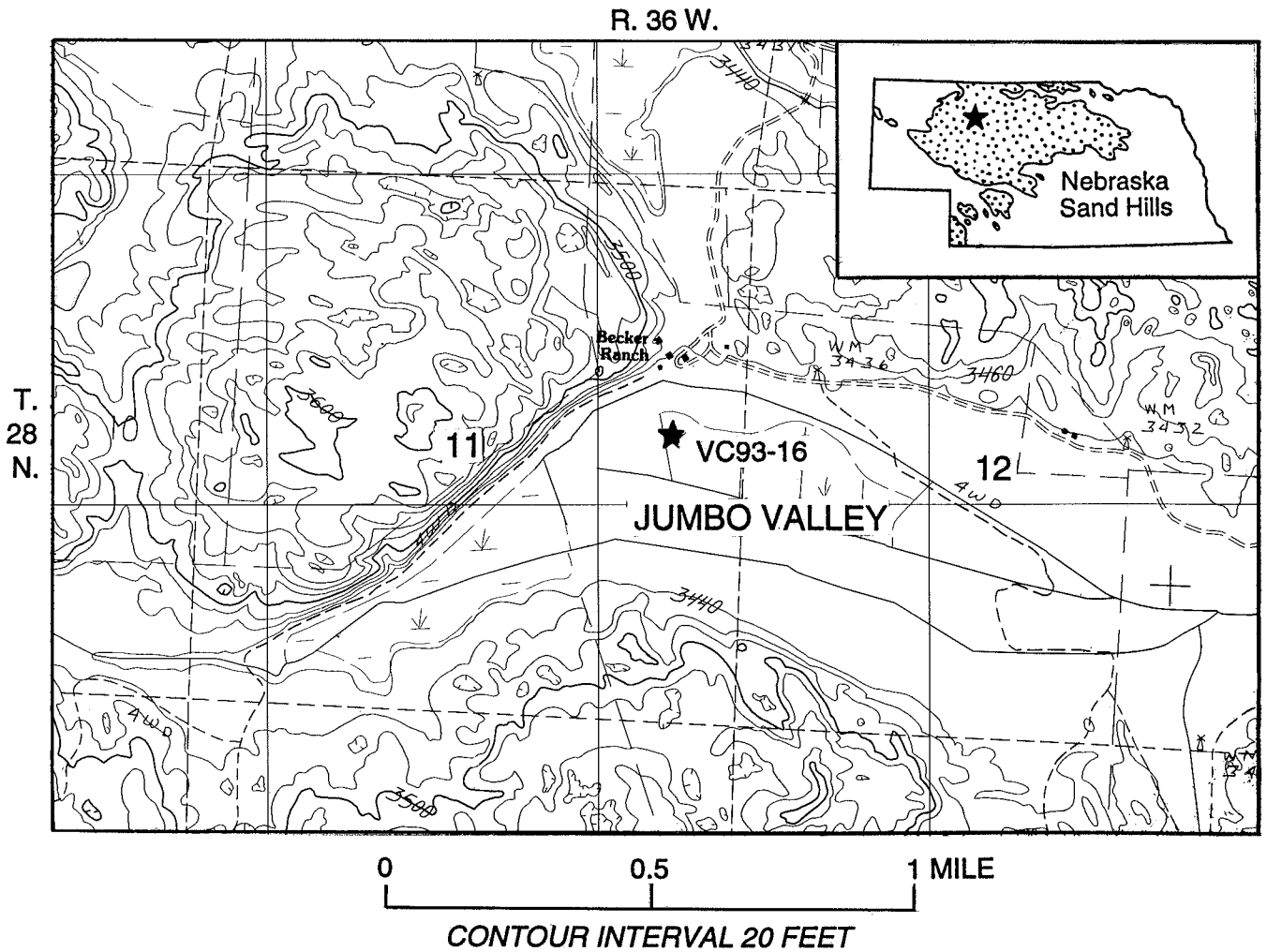
Swinehart and Loope joined Ponte at the site. They eventually found the bottom of the peat at 22-and-a-half feet. Swinehart said he speculated the material at the bottom of the core had to be around 12,000 years old.

While the geologists were taking cores of sand dunes, Chuck Markley, a CSD soil scientist working out of Valentine, was doing soil-survey field work in Cherry County. Markley and other soil scientists found several areas where there were significant thicknesses of peat, or Cutcomb soils.

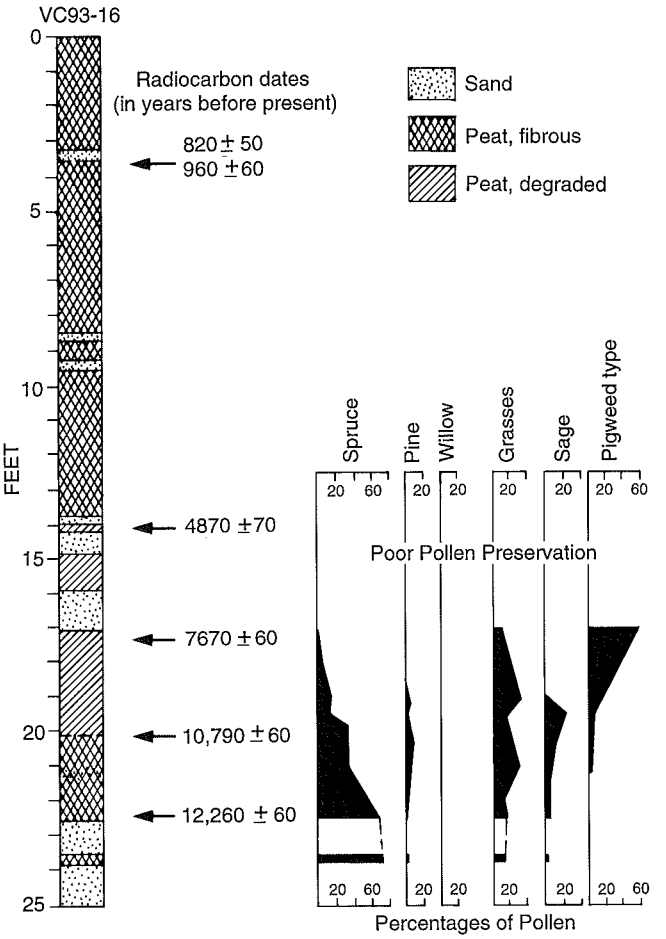
"Ice sheets were still retreating in Minnesota during this period. The climate was cooler and more moist. I suspected we would find spruce pollen," he said.

The bottom of the core was a mixture of red and brown peat with sand; it dated 12,600 years before present. Marga-

Location map showing core from Jumbo Valley in Cherry County. The valley is situated in an area of large dunes.



Mike Ponte, UNL graduate student in geology, records data from a core taken from Jumbo Valley in Cherry County. Dark sections indicate peat interspersed with sand, which is light. Photo by Jim Swinehart, CSD.



Radiocarbon dates of fibrous and degraded peat for Jumbo Valley core. Dates show number of years before present and margin of error. Pollen record from peat layers is on the right. Diagram by Jim Swinehart, CSD.

ret Bolick of the University of Nebraska State Museum determined it had a 70 percent spruce-pollen content.

Several deep cores revealed foot-thick sand layers at around 14 and 18 feet. Radiocarbon dates of the material just below the sand indicated they were between 5,000 and 8,000 years old, respectively. Vegetation records from areas throughout the United States show fluctuating forest-prairie boundaries during this period, Swinehart said.

"There is evidence of warming trends from Texas to southern Canada and from the eastern U.S. to the Colorado plateau, but we didn't have any direct evidence that dunes were moving (during that period)," Swinehart said.

Sand layers indicate moving dunes

The sand layers indicate to Swinehart and Loope that the climate became dry enough between 5,000 and 8,000 years ago for dunes to start moving.

"We hope to determine how quickly climatic change occurs and how many times it's happened in the previous 10,000 years. We can also determine how long these arid periods were," Swinehart said.

The pollen record tells a story of dramatic climate change.

"At 12,000 years ago, where there's 70 percent (spruce) pollen, there almost has to be a spruce forest," he said. "At about 11,000 years ago, there's only 35 percent spruce pollen and the rest is mostly pollen from prairie vegetation. In another 500 years, it's 12 percent. Then 500 years later, it has disappeared. The spruce forest turned to prairie with no evidence of establishment of deciduous trees."

This would indicate a rapid warming and drying of the climate.

"We hope to determine how quickly climatic change occurs and how many times it's happened in the previous 10,000 years. We can also determine how long these arid periods were."

—Swinehart

But to thoroughly explain the number and intensity of climate shifts, he and his colleagues need to understand the hydrology of peatlands, something that is still relatively poorly understood by the scientific community, Swinehart said. In addition, there are some things he and Loope need to become more familiar with.

Need to understand peat degradation

"We need to understand how peat formed in the fens. Dave

and I don't know very much about analyzing the degradation of peat, but it would help us determine the drop in the groundwater table," Swinehart said. "If we can create a hydrology model, we can speculate what would have to occur to make the water table drop by two feet."

Swinehart said they will have to take cores from different sites to see if the Jumbo Valley conditions are consistent. The geologists are already aware of characteristics of some of the fens that are inconsistent with an extended period of drought.

"Plants have been described growing on the fens that were completely out of their range," he said. "Cotton grass, marsh marigold and buckbean. These plants are from cooler, northern climates. They may be glacial relicts. How did they survive the drought period?"

"Ice sheets were still retreating in Minnesota during this period. The climate was cooler and more moist. I suspected we would find spruce pollen."

—Swinehart

The survival of these plants may indicate that areas of the water table were uninterrupted by the drought. The water table may not have dropped below the land surface, which is possible given the occurrence of artesian springs in the Sand Hills.

Swinehart, Loope and Ponte plan to present a paper on the fens at the national meeting of the Geological Society of America in Seattle in October.

"We will propose to do more studies on the fens," Swinehart said. "What is coming through is that fairly substantial changes in the climate have happened very rapidly, maybe within decades."

Jon Mason (left), UNL graduate student in geology, and Dave Loope, UNL professor of geology, use the vibracorer to core shallow saturated sediments in Jumbo Valley, Cherry County. Photo by Jim Swinehart, CSD.

Fossils uncovered a second time for computer data base

Paleontologist resurrects invertebrate fossil data

by Deborah McAdams
Editorial Assistant, CSD

Long before there were buffalo, the Great Plains was a home where invertebrates roamed. In the early 1900s, a small army of geologists collected 7.5 million of the fossilized creatures. The fossils were put into boxes, brown paper sacks or sheets of newspapers, where most of them remained, until recently, said Roger Pabian, a paleontologist with the University of Nebraska-Lincoln Conservation and Survey Division (CSD). Pabian is trying to sort the fossils and create a computer data base with information from the collection.

Many of the fossils were collected by George E. Condra, the director of CSD from 1921 to 1954, and C. O. Dunbar, a researcher from Yale University, during their geological survey of Nebraska, Pabian said. Consequently, Yale developed an invertebrate fossil collection comparable to the one here. Two years ago, Yale opened its collection at the Yale Peabody Museum, Pabian said.

Since the specimens were labeled with numbers and Nebraska had the only existing catalog of the collection, researchers at the Peabody requested a copy, he said. Copies of the catalog were made, but the material needed a great deal of organizing, Pabian said.

"We are trying to resurrect a data base that's been lost for 30 years or so."

—Pabian

Roger Pabian, CSD research geologist, examines some of the fossils being cataloged for an invertebrate fossil data base made from a collection put together mostly between 1921 and 1954 by researchers from the University of Nebraska-Lincoln and Yale University. Photo by Jerry Leach, CSD.

Data base lost for 30 years

"We are trying to resurrect a data base that's been lost for 30 years or so," Pabian said

To organize the catalog, the fossils need to be sorted. They range in size from microscopic, single-celled organisms to the cephalopods, which look like snail shells, some nearly two feet in diameter, Pabian said.

"When I started here 25 years ago, I started some basic unwrapping of specimens when I did the *Record in Rock* book," he said. *Record in Rock* is a handbook of the invertebrate fossils of Nebraska available from CSD.

Pabian is being assisted by Huaibao Liu, who is working on his Ph.D. in micropaleontology.

"After I unwrap it, if it's a good one, I mark it," Liu said. "Some of them are very good, particularly the crinoids."

Crinoids are related to starfish and sea urchins and are recognized by their five-sided structure.

"Some aren't good enough, and some have no labels," Liu said.

He pointed to photographs of some fossils that looked like small nails all pointing the same way, indicating a direction of water flow. The information about water flow is relevant, but the photos are useless.

"We cannot figure out where it came from," Liu said. "When you collect the fossil in the field, you have to make short notes."

Ideally, those notes include the location where the fossil was found, the type and thickness of the rock layer, other types of fossils that were found in the area, and how many of each type were collected.

What kind of environment?

"That can tell you what kind of environment the fossils came from," Liu said. "Was it land, was it sea—and what kind of sea—was it shallow or deeper ocean? Rocks such as limestone indicate there was sea."

"Some collectors were only interested in the fossils, so we don't have data on the rocks," Liu said.

The collection is also valuable because it covers such a long period of time, from 250 to 300 million years before the present. This allows researchers to see changes in the creatures over time.

Primary sorting determines what will remain in the collection. Unlabeled fossils that are in good condition could go to Morrill Hall.

"Some may go to the encounter center at the museum for little kids to dig out of the sand so they can get their junior paleontologist badge," Pabian said.

After deciding what to keep, Liu will sort the specimens by type and location. The collection is especially valuable to researchers because it is arranged according to the rock layers where the fossils were found, Pabian said. Most collections are arranged only by fossils species, or type.

The collection is also valuable because it covers such a long period of time, from 250 to 300 million years before the present. This allows researchers to see changes in the creatures over time.

"My intent is to get it on a data base. Then we will be able to draw up any information we want," said Pabian.

Paleoecologists—those who study ancient ecology—could use the data to determine what ancient environments were like, to understand changes in the environment, and to predict the stability of animal species, Pabian said.

The collection also contains "holotype" specimens—those used to describe a newly discovered species. Pabian has discovered at least 250 holotypes so far.

"A lot of what we have is first-hand information," Pabian said. Pabian is trying to get the collection organized to the point where another organization will be interested in providing funding to house the fossils.

"For a small investment of time and money, we could catalog irreplaceable data," he said.

Unified examining board would include engineers and architects

Draft legislation proposed for registration of state's geologists

Cooperation between engineers and geologists is bringing registration of Nebraska's geologists closer to reality. Registration, which would include an examination and a grandfather clause for current practicing geologists, is a means of assuring professional standards and building a registry of all qualified geologists in the state.

The Nebraska Geological Society (NGS), through an ad hoc committee on registration, is working closely with the State Board of Examiners for Engineers and Architects to propose draft legislation that should be ready by October, in time for the 1995 legislative session, according to Duane Eversoll, associate director of the University of Nebraska-Lincoln Conservation and Survey Division. Eversoll and Jack Shroder, chair of the Department of Geography and Geology at the University of Nebraska at Omaha (UNO), serve as co-chairs of the ad hoc committee.

The movement for geological registration is currently gaining steam as 39 states either have enacted or are considering legislation requiring registration of geologists.

NGS is a nonprofit, professional association of earth scientists and others that meets quarterly to share research and advance the science.

In 1969, the year after it was founded, NGS tried to put its own examining board together but found it was too expensive a proposition, Eversoll said. Then in the early 1970s, some of the engineers and architects tried to include geologists but the move was not successful, he added. However, the movement for geological registration is currently gaining steam as 39 states either have enacted or are considering legislation requiring registration of geologists.

Benefits of registration

According to a brochure put out by NGS, the Iowa-Nebraska section of the American Institute of Professional Geologists and the Department of Geography and Geology at UNO, all of which endorse the registration of geologists, the following are the main benefits of registration:

—"High standards for education, training and experience ensure that geologic work which affects the public welfare will be done by qualified professional geologists."

—"Cost savings will be realized by improving the quality of geologic work on publicly funded projects, minimizing agency review time and eliminating the need for certification of geologists by multiple agencies.

"Cost savings will be realized by improving the quality of geologic work on publicly funded projects, minimizing agency review time and eliminating the need for certification of geologists by multiple agencies."

—Nebraska Geological Society

—"A definition of the practice of geology will provide a legal context for the many references to geology in Nebraska rules and statutes."

—"Enforcement power against unqualified and incompetent personnel will minimize the submission of poor quality geologic work."

The practice of professional geology will be governed by the same board that governs the practice of engineering and architecture. Costs of registering geologists will be covered by licensing fees. There will be no cost to the taxpayer, the brochure says. Such a board could also include landscape architects and interior designers. A new name will be proposed for the board. A single unified board will have the advantages of saving money, enhancing cooperation and streamlining the legislative process, the brochure said.

Costs of registering geologists will be covered by licensing fees. There will be no cost to the taxpayer, the NGS brochure says.

The exam required for registration will be developed in cooperation with the National Association of State Boards of Geology (NASBOG), Eversoll said. NASBOG currently has nine member states and is working to increase membership. A common national examination offers the considerable benefits of reciprocity among states, he added.

Nebraska Geological Society advances the earth sciences

Professional development and educational assistance offered

Since its inception in February of 1968, the Nebraska Geological Society has sought to advance the earth sciences, provide professional development and social opportunities for its members and support earth-science education. It has also worked to set up a board of examiners to register geologists, an effort that soon may be bearing fruit in Nebraska (see related story in this issue).

Open to anyone with a bachelor's degree in geology or a related science, the society also offers associate memberships for the interested lay person and student memberships. It holds quarterly meetings that alternate between Lincoln and Omaha and involve dinner and a presentation. In the spring, members take a yearly field trip, usually in conjunction with the annual meeting of the Nebraska Academy of Sciences. It also sponsors a research grant given to one or more earth-science students at a Nebraska college or university, as well as offering an award for the best student paper given at the Nebraska Academy of Sciences annual meeting, explained Marv Carlson, research geologist with the University of Nebraska-Lincoln Conservation and Survey Division (CSD).

Early membership came mostly from the ranks of university employees and from state and federal agencies, and the vast majority had degrees in geology, Carlson said. Now, a growing number of members are from the private sector, particular engineering geologists and hydrogeologists working for consulting companies, he added. That transition from more basic to more applied research reflects the changing profile of geologists operating in Nebraska, as environmental regulations require more geologic research, much of which is supplied by consultants, Carlson said. In addition, the society now offers membership to soil scientists, geographers and members of the mining industry. NGS members currently number 208, according to Ted Huscher of Coranco, Inc. of Wahoo, who is the society's secretary.

Society's field trips

The society's field trips are led by volunteers who choose where the trips will go, explained Roger Pabian, research geologist with CSD and former society secretary and field trip leader. Some interesting field trips have been looking at the Pleistocene in eastern Nebraska, examining Late Paleozoic strata in the eastern part of the state and looking at the Cretaceous in south-central Nebraska, he said. Other trips have emphasized economic geology and have visited limestone quarries, sand and gravel pits or cement manufacturing plants.

In the area of outreach work, a growing relationship has emerged between the society and the Nebraska Earth Science Education Network (NESEN), an organization set up by members of the Conservation and Survey Division, the University of Nebraska State Museum, the UNL geology department and others to allow K-12 educators to collaborate with university earth scientists on developing curricula for earth-science education, (see related story in this issue). The society also interacts with CSD as a conduit to both provide current information to society members and provide CSD with emerging needs for geologic data required to solve environmental problems, he added.

Another important service the society will provide will be helping with the upcoming joint annual meeting of the North-central and South-central sections of the Geological Society of America to be held in Lincoln April 27-28, 1995 (see related story in this issue).

Program encourages communities to act to preserve groundwater

Groundwater Guardian targets eight communities

by Deborah McAdams
Editorial Assistant, CSD

Eight communities throughout the United States and Canada are serving as test sites for a program developed by the Lincoln-based Groundwater Foundation. The Groundwater Guardian program encourages communities to become actively responsible for the protection of their groundwater.

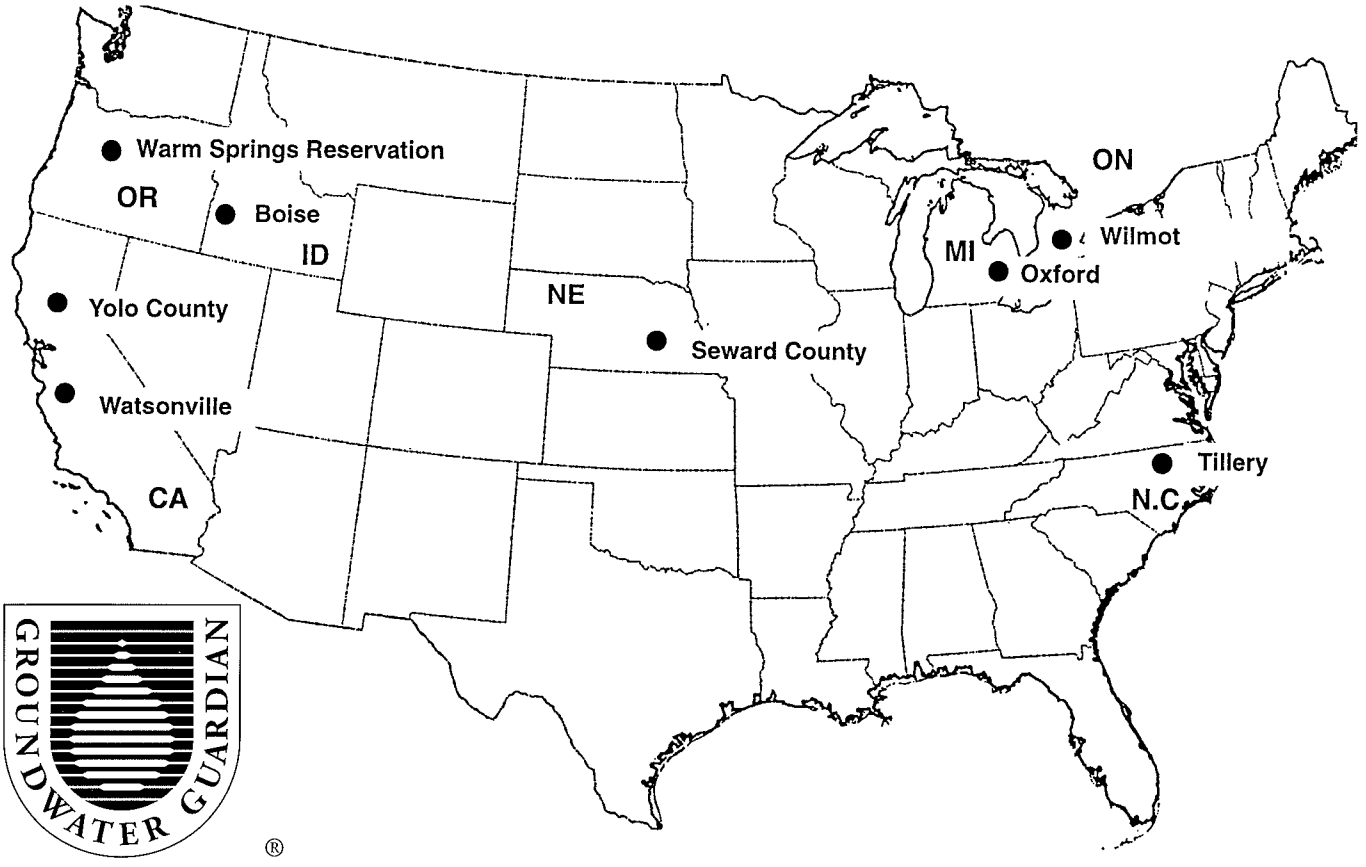
The program grew out of a project initiated by the Kellogg Foundation. Kellogg had given the Groundwater Foundation, formerly the Nebraska Groundwater Foundation, funding to develop a network of projects in the Great Lakes basin similar to the Groundwater Education program in Michigan. As part of this network, the Foundation had worked with land-use planners who could provide services to Great Lakes basin communities. One problem with this network concept was sustaining it after the funding from the Kellogg Foundation ended.

"I always wonder when I get money, what's going to happen when the money's gone," said Groundwater Foundation president Susan Seacrest.

"I've always had in the back of my mind a program similar to the National Arbor Day Foundation's Tree City USA, a program that recognizes communities for groundwater protection like they do for planting trees."

—Seacrest

A solution to this problem was to develop a community-based and -driven program that would be self-sustaining, in



Location of Groundwater Guardian communities

which the communities would assume ownership of the program, she said.

Seacrest and Bob Kuzelka, Groundwater Guardian program director and assistant to the director of the University of Nebraska-Lincoln Water Center/Environmental Programs, approached the Kellogg Foundation with the idea of a community-based groundwater-protection program.

"I give (the Kellogg Foundation) a lot of credit because they agreed to do it," Seacrest said.

Program like Tree City USA

"I've always had in the back of my mind a program similar to the National Arbor Day Foundation's Tree City USA," Seacrest said, "a program that recognizes communities for groundwater protection like they do for planting trees."

"We were looking for geographic, cultural and groundwater diversity. We were looking at communities that were a challenge."

—Seacrest

Two groups of groundwater and community specialists from all over the country started putting together an instructional guide for the new program. At the same time, they were also looking at communities where the guide could be tested.

"We were looking for geographic, cultural and groundwater diversity," Seacrest said. "We were looking at communities that were a challenge. We used our existing contacts and elbow grease."

The groups suggested some communities, as did the U.S. Environmental Protection Agency and the U.S. Geological Survey. Communities had to have groundwater as a water-supply source and did not have to be an incorporated body such as a city or county, Kuzelka said.

Seward County, Neb., and communities on both coasts and in the Great Lakes region, including one in Canada, were selected to participate in the Groundwater Guardian test year.

Communities selected

The communities and their groundwater conditions are as follows:

—In Seward County, Neb., where nitrates are compromising the water quality, groundwater is the only source of drinking water for nearly 16,000 people.

—A majority of the 3,000 people of non-incorporated Tillery, N.C., are African-American farmers. Most of their drinking water comes from older, individual shallow wells in which the quality of water is being threatened by a nearby intensive hog operation.

—The Warm Springs Indian Reservation covers nearly 9,000 square miles of Oregon countryside crossed by clear-running streams fed by groundwater. Three thousand people of the Confederated Tribes are concerned that development on the reservation will contaminate the groundwater and, thus, the streams.

—More than 80 public drinking wells are located within the city limits of Boise, Idaho, where the aquifer system is directly beneath the city of 140,000. Contaminants were dis-

covered in the groundwater five years ago, and the city created a groundwater coordinator position. Since then, they have developed a pilot wellhead-protection project and made efforts to educate the public about the issue. Officials in Boise, which has been experiencing an extended drought, remain concerned about both the quality and quantity of their drinking water, according to Catherine Chertudi, the Groundwater Coordinator at the Boise Public Works Department. The situation in the community is compounded by one of the fastest growing populations in the nation.

—Three municipal wells supply drinking water for 2,900 people in the village of Oxford, Mich., a suburb of Detroit. The community is located on top of a major aquifer that sits under most of surrounding Oakland County. Groundwater in the area is particularly vulnerable to contamination because the soil is primarily porous sand and gravel. Potential sources of contaminants are residential development, abandoned landfills, old gas stations and aging industrial sites. Oxford has been recognized by the state of Michigan for its wellhead-protection program. Village officials are now mobilizing to encourage citizen involvement and develop public education.

—The 141,000 citizens of Yolo County in the San Joaquin Valley of California get all of their drinking water from groundwater. Both surface water and groundwater are used for irrigation in the heavily farmed valley.

—In the strawberry-production capitol of the world, Watsonville, Calif., all potable water comes from the Pajaro Valley drainage basin aquifers. These aquifers have been nearly depleted, and saltwater intrusion threatens the drinking-water source for the area's 75,000 people.

—The township of Wilmot, Ontario, uses groundwater as the sole source of its drinking water and is the source of water for 30 percent of the needs of the townships and cities to the east. Groundwater is also used for agriculture in the township. It is one of the most groundwater-rich areas in Canada, and the nearby University of Waterloo conducts a major groundwater research program.

Communities put together Guardian team

Each of these communities had to put together a Groundwater Guardian team before they were admitted into the program. The teams had to include people from four community sectors: business and agriculture, government, education and concerned citizens or organizations, Kuzelka said.

The Groundwater Foundation provided the communities with a series of resources, including "A Community Guide to Groundwater Guardian," the program's instruction manual.

The team creates results-oriented activities, Kuzelka said. They must adopt a program of activities and begin implementation.

The teams had to include people from four community sectors: business and agriculture, government, education and concerned citizens or organizations, Kuzelka said.

Results-oriented activities may be public awareness and education activities, conservation programs, wellhead-protection projects, public-policy activity or improved management practices in agriculture.

The communities don't necessarily have to finish the projects during their first year. But they have to begin them, Kuzelka said.

"They send us an annual report from which we determine their status as a Groundwater Guardian community," he said.

"We're very committed to the team approach," Seacrest said. "We trust the communities to do the right thing, and we'll support them in it. It's the opposite of many regulatory agencies that assume communities or people are trying to get away with whatever they can," she said.

"The problems develop over time, and the solutions develop over time," Seacrest said. Community involvement is vital for developing solutions, she added.

With the help of Rep. Doug Bereuter (R-Neb.), Seacrest notified members of Congress whose states or districts had communities in the test-year Groundwater Guardian program. She went to Washington, D.C., in late July to meet with their water-resources staff people.

The communities that successfully complete the test year will be recognized at a national conference in Washington, D.C., on November 17 and 18, when the program will be launched for 1995 and beyond.

NESEN expands membership, mails guide and directory

First two earth-science education workshops offered

by Duane Mohlman
Data Systems Coordinator, CSD,
and NESEN Steering Committee Member

In addition to increasing its membership to 130 during the past year, the Nebraska Earth Science Education Network (NESEN) sent the first *NESEN Information Guide and Membership Directory* to all NESEN members this past spring and put on its first two workshops this summer.

The 37-page directory includes many sources of earth-science information and educational opportunities in Nebraska and the United States; instructions on how to access Internet, including NESEN's news group entitled unl.nesen; a listing of education-related Internet news groups; a complete listing of all members; and more. If available, each member's complete work address, home and work telephone numbers and e-mail addresses were provided. These complete address listings are provided to encourage interaction among earth-science teachers, as well as between teachers and the post-secondary earth-science community.

During the spring of 1994, several educational materials were sent to members. Some of these materials included exercises to enhance teaching about Nebraska's soils, topographic regions and bedrock. Other learning activities are

being planned.

Two two-day workshops

In July, NESEN sponsored two workshops (see related story in this issue). These two-day workshops, entitled "What is in a Rock?" and "Nebraska's Water System: A Geoscientist's Approach," were designed to be interactive and provide hands-on experience for teachers on various earth-science topics in Nebraska. Emphasis was also given to where and how to get earth-science information in Nebraska. The workshops were pilot projects that provide a basis for developing a workshop series accessible to all Nebraska teachers.

As is indicated by these activities, NESEN continues to grow and expand its activities since its inception in 1992. Currently, approximately 90 K-12 Nebraska earth-science teachers—about 30 percent of the earth-science teachers in Nebraska—and about 40 post-secondary educators, mostly from the University of Nebraska-Lincoln, have joined.

As is indicated by these activities, NESEN continues to grow and expand its activities since its inception in 1992. Currently, approximately 90 K-12 Nebraska earth-science teachers--about 30 percent of the earth-science teachers in Nebraska--and about 40 post-secondary educators, mostly from the University of Nebraska-Lincoln, have joined. A steering committee of 15 members, comprised of both K-12 teachers and UNL staff, continues to plan and direct NESEN activities.

In October 1993, NESEN participated in the annual Nebraska Association of Teachers of Science (NATS) Conference at Camp Calvin Crest near Fremont, Nebraska. Besides having NESEN information available at the UNL Conservation and Survey Division (CSD) booth, the NATS Conference included the inaugural NESEN-sponsored Lesson Plan Share-a-Thon. Although there were only five presenters, more than 60 teachers acquired the presenters' materials. Plans are underway for an expanded Share-a-Thon and other NESEN-sponsored activities at the 1994 NATS Conference. Also at the 1993 NATS Conference, Francis Belohlavy, CSD soil scientist, Dave Gosselin, CSD research geochemist, and Bob Feurer, of North Bend High School, conducted presentations on Nebraska's soils and on "Nebraska's Water from the Land and in the Air." Between 20 and 30 teachers attended and received educational materials from these presentations.

NESEN quarterly newsletter

Beginning in 1993, a NESEN quarterly newsletter was also established. This 2-page newsletter serves as an excellent source of earth-science information. Some of the topics frequently covered in the newsletter include: advising members of upcoming earth-science activities and meetings, providing additional sources of earth-science instructional materials and announcing new CSD publications.

NESEN also recognizes that the state geological surveys, such as the Conservation and Survey Division, are an underused, but valuable, source of earth-science information and materials for K-12 educators throughout the country. As a result, the NESEN Steering Committee is in the process of considering potential activities for the joint meeting of the North-central and South-central sections of the Geological Society of America (GSA) in April 1995 to enhance communication between state surveys and the K-12 earth-science teaching community. This meeting will be co-sponsored by CSD and held at the Nebraska Center for Continuing Education and at the UNL East Campus Union (see related story in this issue).

A featured activity at GSA will be a share-a-thon of public information and educational materials available at the state surveys. At the same time, a lesson plan share-a-thon among teachers will take place. Conducting both share-a-thons simultaneously means that teachers can see what materials are available from other states, as well as giving the state surveys a chance to see what types of materials teachers use and need. In addition, state surveys are being encouraged to sponsor a teacher from their state to attend the GSA meeting. Sponsorship can be accomplished in several ways: direct financial support from the state survey or assistance from institutions such as the American Association of Petroleum Geologists, GSA or local geological societies.

Other possible activities at GSA include exhibits, a luncheon with keynote speaker and a possible panel discussion on earth-science education. Overall, the day is designed to provide teachers with an opportunity to learn more about the earth-science community and to establish links with earth-science professionals both in industry and post-secondary education.

Involved with math and science initiative

NESEN is also trying to become more involved with the Nebraska Math and Science Initiative (NMSI). NMSI is designed to develop an infrastructure for improving science and mathematics education within the state. Some NMSI programs include: the K-12 Curricula Enhancement Project; Practical Pre-College Math; Math Vantage; and the development of a statewide electronic network.

NMSI will soon create seven regional coalitions that will include the state's 19 Educational Service Units (ESU). These

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coalitions are designed to improve professional development opportunities and increase public support for math and science education. Gosselin and Belohlavy represented NESEN at a February 1994 meeting with NMSI officials. They explained NESEN's mission of trying to improve cooperation between K-12 educators and university staff and the potential for assistance and cooperation between NESEN and NMSI. Science teachers should contact their local ESU for further information about coalition development in their area.

NESEN is also a member of the Coalition for Earth Science Education (CESE), which is a national organization designed to promote communication among its members and to facilitate cooperative projects in earth-science education. Organizations can work on projects individually, but through CESE, they can find out what types of projects other member organizations are working on or have completed. This "clearinghouse" effort should aid organizations as they develop projects and also assist teachers. Teachers can now contact one source, CESE, for earth- and space-science information. The CESE planning committee is sponsoring information sessions at professional meetings and will once again have a booth at the 1994 meeting of the National Science Teachers Association in Anaheim, California.

NESEN membership is open to any earth-science educator interested in improving the instruction of earth science. Membership is free. If you would like to become a member or want further information, contact CSD, 113 Nebraska Hall, UNL, Lincoln, NE, 68588-0517; or call (402) 472-3471; or e-mail CSD at negeosrv@unlinfo.unl.edu. Further historical information about NESEN can be found in the 1992-1993 issue of *Resource Notes,* available from CSD.

Schools selected for satellite and space-shuttle downlink

NASA funding allows Nebraska schools to participate

Some Nebraska K-12 students will soon have direct access to satellite and space-shuttle information through a new computer network. The National Aeronautics and Space Administration (NASA) has agreed to provide funding for a pilot project that will bring students closer to the earth through space-age technology. Nine or ten schools around the state will be selected to participate, said David Gosselin, research geochemist with the University of Nebraska-Lincoln Conservation and Survey Division (CSD) and coordinator of the Nebraska Earth Science Education Network (NESEN).

The pilot schools will have to be hardwired, or hooked up, to an appropriate communications infrastructure. The infrastructure typically consists of adding special equipment, or routers, to existing telephone lines of each Educational Service Unit (ESU). The Nebraska Division of Communications is in the process of developing the infrastructure so schools can have access to the Internet, a worldwide computer network, said Douglas Gale, director of the UNL Computing Resource Center.

"There is no uniform infrastructure throughout the state," Gale said. "Not all ESUs are hooked up."

Consequently, some of the pilot sites will be very easy to hardwire and others will require completion of the infrastructure. Half of the grant money will go into completing the infrastructure, and the rest will be used to make the NASA information useful and understandable for both students and teachers.

Computer experience and literacy varies among teachers, Gosselin said. NESEN will be involved in hiring someone who can translate the NASA data into K-12 lesson plans.

Part of the purpose of the pilot program is to see if it's even possible to make such data useful in the classroom, Gale said. If the results don't justify the effort, students may not continue to receive information directly from space, but they will be left with greater access to the world through the Internet, Gale said.

Classroom and field activities illustrate geologic history

Teachers respond favorably to first NESEN workshop

The Nebraska Earth Science Education Network (NESEN) received positive responses to its first teach ers workshop in early July. Eight Nebraska teachers participated in the two-day workshop conducted by Conservation and Survey Division geologists Dave Gosselin and Marv Carlson at the University of Nebraska-Lincoln and in the field in southeastern Nebraska.

The focus of the first day was classroom activities and exercises that used rocks to illustrate Nebraska's geologic history. The next day, the teachers were taken on a field trip where they collected rock specimens at Rock Lake Quarry, visited the Gretna State Fish Hatchery and explored a sandbar in the Platte River.

"I had a really good time," said Susan Frack of Lincoln. Frack teaches 8th-grade earth science at Raymond Junior High School. "Marv did a 'Bag-of-Rocks' activity with us where we had to identify and classify several rocks. I plan to use an activity like that in my classroom," Frack said.

All of the teachers appreciated the field trip, based on comments from workshop evaluation forms.

"Due to the hands-on nature (of the experience), this workshop was more enjoyable than most," one participant wrote.

"Geologic history of Nebraska was something I knew little about," another teacher wrote.

Workshop meets specific needs

Frack said she found this workshop especially useful for her needs.

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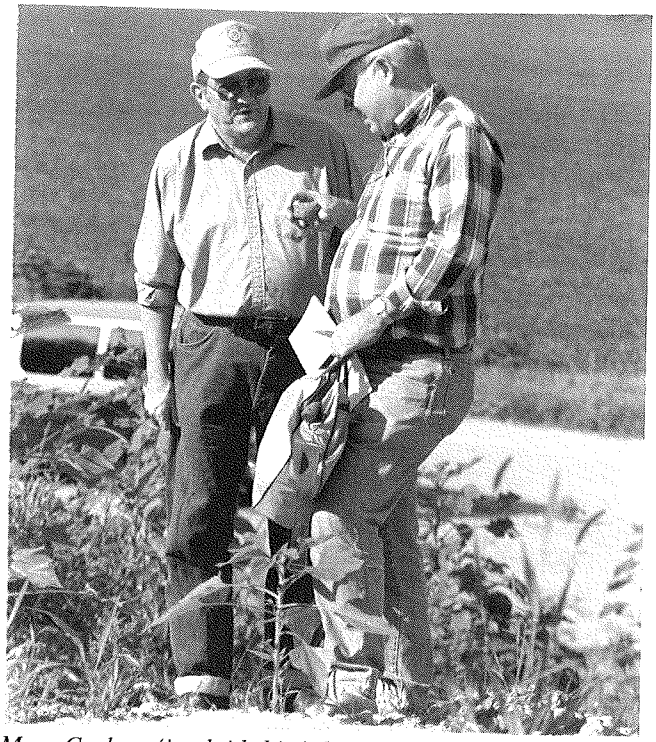
—Frack

"There have been some (workshops) at the university on environmental science that the Arbor Day Foundation has done. Lots of times, you get stuff on biology and chemistry,



Marv Carlson (in plaid shirt) discusses a rock sample with a teacher participating in the first Nebraska Earth Science Education Network workshop. Photo by Deborah McAdams, CSD.

but not really (on) earth science," she said.

Frack intends to take her enthusiasm about the workshop back to her students, she added.

"Not very many kids seem to be interested in going into scientific research. Maybe some of this will help us steer kids that way," she said.

Richard Bagger has been steering kids through chemistry, physics and earth science for 35 years. He attends education workshops for motivation, he said.

"I like to come to these (workshops) because they rejuvenate me. I get so tired during the school year. This is my refreshment."

—Bagger

"I like to come to these (workshops) because they rejuvenate me. I get so tired during the school year. This is my refreshment."

Al Musson said that he doesn't get burned out teaching earth science, although he's done it for 27 years.

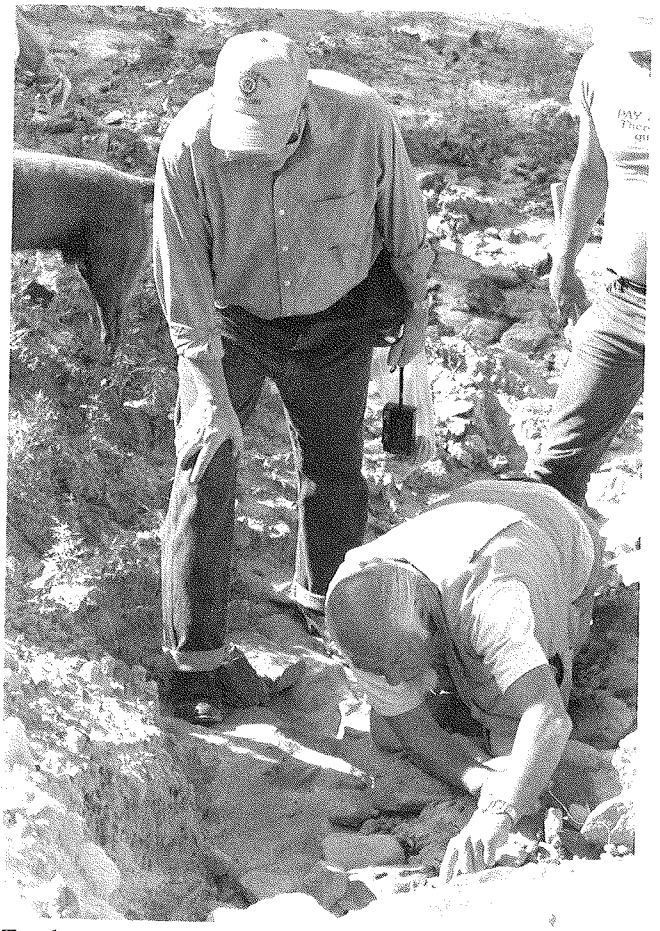
"This is the most exciting thing that ever happens. It's all new kids each time," he said.

"We start with rocks and minerals. Those are the bones of the earth. Then we build on those," he said. "The extent to which I go depends on the interest of the kids."

Field trip replenishes rock collection

Musson also used the field trip to replenish the rock collection he uses in the classroom.

"Various science companies will sell specimens, but their prices are at a premium, so for a tank of gas, I can get the materials I need," he said.



Teachers taking part in the Nebraska Earth Science Education Network workshop on Nebraska geology examine a rock layer at Rock Lake Quarry. Photo by Deborah McAdams, CSD.

Musson's expenses were limited to a tank of gas because the Midcontinent Section of the American Association of Petroleum Geologists (AAPG) contributed $1,200 to be used as a stipend for teachers participating in the workshops. The AAPG, through the Nebraska Geological Society, supports both formal earth-science education and public awareness programs. Materials from the workshops will be made available to earth-science teachers throughout the Midcontinent area.

"We start with rocks and minerals. Those are the bones of the earth. Then we build on those. The extent to which I go depends on the interest of the kids."

—Musson

More materials will be available if the success of the first NESEN workshop is any indication. Topics suggested by the teachers for future workshops included earthquakes, roadside geology, soils and mapping.

Frack said she planned to attend future workshops.

"I'm really happy that Dave and Marv took the time out to help us," she said.

Automated data bases available on a variety of subjects

Division computing supervisor makes maps with machines

by Karen Stork
Administrative Assistant, CSD

The twenty-first century is right around the corner. We believe it will be an age of robotics, artificial intelligence and digitized information.

And the University of Nebraska-Lincoln Conservation and Survey Division (CSD) is preparing for the transition to total automation with the aim of producing computer-generated maps on demand. The final goal is to serve the public with instantly retrievable data in many forms. To achieve this, all of the division's natural-resource datasets must be entered into a computerized data base. Because the amount of data stored is so vast and cumbersome, it's necessary to use a data-base manager, a computer program that provides a way to find specific data in a large dataset. This electronic data-base manager is a different sort from the human data-base manager that must manage the electronic ones.

"Every piece of data is identified by a series of 'X-Y' locations and an attribute," Weir notes. An attribute tells what the data represents or gives additional information, such as whether the data is a test hole, how deep the hole is, the depth to water and so on.

As computing supervisor at CSD, Jim Weir has been busy helping the division manage electronic data bases and meet the other goals related to the information age. Weir was a junior high earth-science teacher from 1969 to 1984 in Central City, so he understands the concepts and terminology of geology and geography. He took up computer science as a hobby in the early 1980s and in 1984 decided to make a career change into full-time computing. His job at CSD combines both interests.

Jim manages the division's ARC/INFO computer system. ARC refers to lines and their locations, and INFO is the data-base manager, Weir explains.

Nearly every piece of data referenced to a place

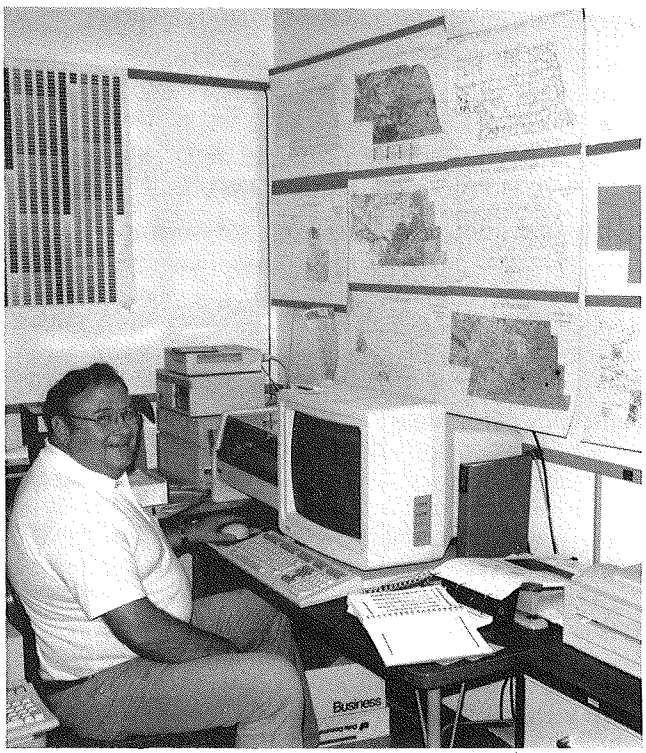
"Almost every piece of data we have is referenced to a place," he says. "Traditionally, most features were located using the legal description. However, it's not ideal for computer mapping." The ARC/INFO system then converts this legal description to a Cartesian coordinate system represented on a map by an "X" for the horizontal location and a "Y" for the vertical location.

"Every piece of data is identified by a series of 'X-Y' locations and an attribute," he notes. An attribute tells what the data represents or gives additional information, such as whether the data is a test hole, how deep the hole is, the depth to water and so on.

To make the system work, all attributes must first be typed into the data-base manager, including the legal description. The computer then translates that description into "X" and "Y" coordinates. Finally, when all this information is entered, computer-generated maps can be produced either on a computer screen or on paper.

Weir has been working on producing computer-generated maps from the division's statewide data bases for many years.

"The most important part of this whole process," he says, "is consistency and accuracy of the data." To achieve this, all computer-generated maps are reviewed by a CSD faculty member.



Jim Weir, CSD computing supervisor, calls up a statewide data base on one of the computers in his office. On the wall above him are the automated maps made from various statewide data bases. Photo by Jerry Leach, CSD.

Many data bases automated

A few of the many CSD data bases that have been automated and used to produce statewide, computer-generated maps include: oil and gas wells, earthquakes, landslides, land use, lakes, major roads, mineral operations, nitrates in wells, natural resources district (NRD) boundaries, center-pivot irrigation systems, railroads, registered wells, roads, range and township, sections, streams, soils, test holes, topography, towns, watershed boundaries, water levels and many more.

Some of the division's datasets have been obtained from other agencies.

"And we also share our data with other agencies," Weir says. Some of the data used to generate maps is "derived," meaning the computer generates new information by combining old datasets in new ways.

An example of a derived dataset is one based on the listing of section corners from the Nebraska Natural Resources Commission. Weir connected the corners with lines that then gave the shape and location of each section covering the state--82,000 section polygons.

"From this information, I can map anything located within a section such as a well or gravel pit," he says.

Another example of a derived dataset is one using STATSGO--a statewide soils data base. One of CSD's soil scientists took the existing STATSGO data--a classification of soils completed cooperatively by CSD and the USDA Soil Conservation Service--and from that derived parent-material and water-erosion indexes. Now scientists have easy access to what the soils are made of and which soils are more likely to erode. And Weir can produce a computer-generated map showing this information.

The production of computer-generated maps is just the latest in a long line of informational products that the division has available for the public.

"The most important part of this whole process," Weir says, "is consistency and accuracy of the data." To achieve this, all computer-generated maps are reviewed by a CSD faculty member.

Anticipate client requests

"We try to anticipate requests from clients, and that's the reason for the long list of automated data bases," he says.

Weir estimates that he probably averages about four requests a week for computer-generated maps. He gives the following examples of recent requests for maps:

—The city of Gothenburg was preparing a community grant and needed to know how many center-pivot systems were located within a 50-mile radius of the community.

—The Tri-Basin NRD wanted a map of all the registered wells in the NRD, classified by the diameter of the well casing.

—The Nebraska Department of Roads needed the location of all active quarries, pits and mines using latitude-longitude coordinates.

—An engineering consultant needed to know the locations of all registered wells west of the Blue River in Seward County, together with a 1,000-foot exclusion zone around each well. This would indicate the areas where a municipal water well could be drilled.

One of Weir's largest recent tasks has been providing specific computer-generated maps for many of the NRDs as they develop their groundwater-management plans. All of the NRDs have requested various kinds of information from members of the division staff, and Weir personally filled requests for six NRDs himself.

Not free but still a good deal

He reminds users that the development of computer-generated maps from existing automated data bases isn't cheap or free. However, it's still a good deal.

"We charge only time (which includes both computer and staff time) and materials," he says.

Other state geological surveys that have been active in this area include Illinois (especially in ARC/INFO and interpreting glaciated regions) and Kansas (in delivering information to the public). And CSD is moving up fast.

Although CSD sometimes has been hampered in its effort by a lack of staff to input data, Weir feels the division is one of the leaders in this field, especially with the development of the Center for Advanced Land Management Information Technologies (CALMIT). Geographic information systems (GIS) technology has revolutionized the field of computer-generated maps.

A few of the many CSD data bases that have been automated and used to produce computer-generated statewide maps include: oil and gas wells, earthquakes, landslides, land use, lakes, major roads, mineral operations, nitrates in wells, natural resources district boundaries, center-pivot irrigation systems, railroads, registered wells, roads, range and township, sections, streams, soils, test holes, topography, towns, watershed boundaries, water levels and many more.

"We're going to computers because they're fast and can put data together very quickly," he says. "And then it's easier for the scientist or administrator to interpret the data more quickly."

"We try to anticipate requests from clients, and that's the reason for the long list of automated data bases."

—Weir

Weir says he feels he has made good progress on automating CSD's data bases, even if a major part of his time is spent providing computer support for CSD faculty members and staff--repairing worn-out computers, installing new hardware and software, helping staff learn e-mail and other activities.

"Occasionally," he notes, "I have to decide whether or not I'm going to make a map or solder a circuit board."

Selected publications related to this issue

Publications

—Brachiopoda of the Pennsylvanian System in Nebraska: Dunbar, C.O., and Condra, G.E. (1932) - $4.25 (GSB-5)

—Nautiloid Cephalopods of the Pennsylvanian System in Mid-Continent Region: Miller, A.K., Dunbar, C.O., and Condra, G.E. (1933) - $3.50 (GSB-9)

—Centennial Guidebook to the Geology of Southeastern Nebraska: Burchett, R.R., and Reed, E.C., with contributions from the staff of the Conservation and Survey Division (1967) - $3.50 (GB-2)

—Guidebook for Field Trip on Urban Geology in Eastern Nebraska: Wayne, W.J. (1971) - $3.50 (GB-5)

—GSA Guidebook to the Late Pennsylvanian and Early Permian Cyclic Sedimentation, Paleogeography, Paleoecology, and Biostratigraphy in Kansas and Nebraska: Pabian, R.K., and Diffendal, R.F., Jr. (1989) - $4 (GB-9)

—Flat Water: A History of Nebraska and Its Water: Kuzelka, R.D., project manager, and Flowerday, C.A., editor (1993) - $20 (RR-12)

—Wetland Inventories of Nebraska's Sandhills: Rundquist, D.C. (1983) - $3.25 (RR-9)

—The Groundwater Atlas of Nebraska: Kuzelka, R.D., and Pederson, D.T., project leaders (1986) - $3.50 (RA-4)

—An Atlas of the Sand Hills: Bleed, A.S., and Flowerday, C.A., editors (1990); paper bound - $15 (RA-5a)

—Record in Rock--A Handbook of the Invertebrate Fossils of Nebraska: Pabian, R.K. (1970) - $4 (EC-1)

—Geologic History of Ash Hollow Park, Nebraska: Diffendal, R.F., Jr., Pabian, R.K., and Thomasson, J.R. (1981) - $3.75 (EC-5)

—Late Paleozoic Cyclic Sedimentation in Southeastern Nebraska: A Field Guide: Pabian, R.K., and Diffendal, R.F., Jr. (1991) - $5.50 (EC-9)

—Geology, Geologic Time and Nebraska: Carlson, M.P. (1993) - $5.50 (EC-10)

—Fundamentals of Groundwater Contamination: Pederson, D.T. (1994) - $4.50 (EC-11)

—Taxonomy, Paleoecology and Biostratigraphy of the Crinoids of the South Bend Limestone (Late Pennsylvanian-Missourian, ? Virgilian) in Southeastern Nebraska and Southeastern Kansas: Pabian, R.K., and Strimple, H.L. (1993) - $6.50 (PP-1)

—Nebraska Earth Science Education Network Membership Directory and Information Guide: Mohlman, Duane; Gosselin, Dave; and Belohlavy, Francis, compilers (1994) - Free to members

—Numerous master's theses on invertebrate fossils from the 1930s (in the UNL Geology Library)

Reprints

—Dynamic Holocene Dune Fields of the Great Plains and Rocky Mountain Basins, U.S.A., *in Eolian Sediments and Processes*, Elsevier Science Publishers, The Netherlands: Ahlbrandt, T.S., Swinehart, J.B., and Maroney, D.G. (1983) - $2 (RS-41)

—Cenozoic Paleogeography of Western Nebraska, *in* Proceedings of the Rocky Mountain Paleogeography Symposium 3, Rocky Mountain Section, Society of Economic Paleontologists and Mineralogists: Swinehart, J.B., Souders, V.L., DeGraw, H.M., and Diffendal, R.F., Jr. (1985) - $2 (RS-52)

—Decade of North American Geology Field Guides for Nebraska, *in The Decade of North American Geology Field Guides, The Geology of North America, 1987*: Nebraska Geological Survey, Department of Geology, and Nebraska State Museum, University of Nebraska-Lincoln - $2.00 (RS-71)

—Collecting in Nebraska's Pennsylvanian-Permian Strata, *in* Rocks and Minerals 55, No. 2, May-June, 1980: Pabian, R.K. - $1.50 (RS-73)

—Field Guide to Geology and Hydrology of the Nebraska Sand Hills, *in Geological Society of America Field Trip Guidebook, 1988*, Professional Contributions, Colorado School of Mines, No. 12: Swinehart, J.B., Goeke, J.W., and Winter, T.C. - $1.50 (RS-83)

—Classification, Paleoecology, and Biostratigraphy of Crinoids from the Stull Shale (Late Pennsylvanian) of Nebraska, Kansas, and Iowa, Bulletin of the Nebraska State Museum, Vol. 11, No. 1, March 1985: Pabian, R.K., and Strimple, H.L. - $1.50 (RS-84)

—Comments on the Geologic History of the Ogallala Formation in the Southern Panhandle of Nebraska, *in* Proceedings of the Ogallala Symposium II, 1984: Diffendal, R.F., Jr. - $1.50 (RS-90)

—Methods for Estimating Wetland Loss: The Rainbasin Region of Nebraska, 1927-1981, *in* Journal of Soil and Water Conservation, Vol. 46, No. 6, November/December, 1991: Kuzila, M.S., Rundquist, D.C., and Green, J.A. - $1.50 (RS-147)

—Late Paleozoic Trilobites from Southeastern Nebraska *in* Journal of Paleontology, Vol. 46, No. 6, November 1972: Pabian, R.K., and Fagerstrom, J.A. - $1.50 (RS-154)

—Development of a Land-Cover Characteristics Database for the Conterminous U.S., *in* Photogrammetric Engineering & Remote Sensing, November 1991, Vol. 57, No. 11: Loveland, T.R., Merchant, J.W., Ohlen, D.O., and Brown, J.F. - $1.50 (RS-153)

Maps

—Seasonal Land Cover Regions of the Conterminous United States: U.S. Geological Survey EROS Data Center (1:7,500,000) - $4 (LUM-32)

—Geologic Bedrock Map of Nebraska, 1986: Burchett, R.R.; color print (1:1,000,000) - $4.50 (GMC-1)

—Bedrock of Nebraska with Geologic Time and Rock Chart, 1991: compiled by Burchett, R.R., and Pabian, R.K.; color print (11" x 17") - $0.50 (GMC-2)

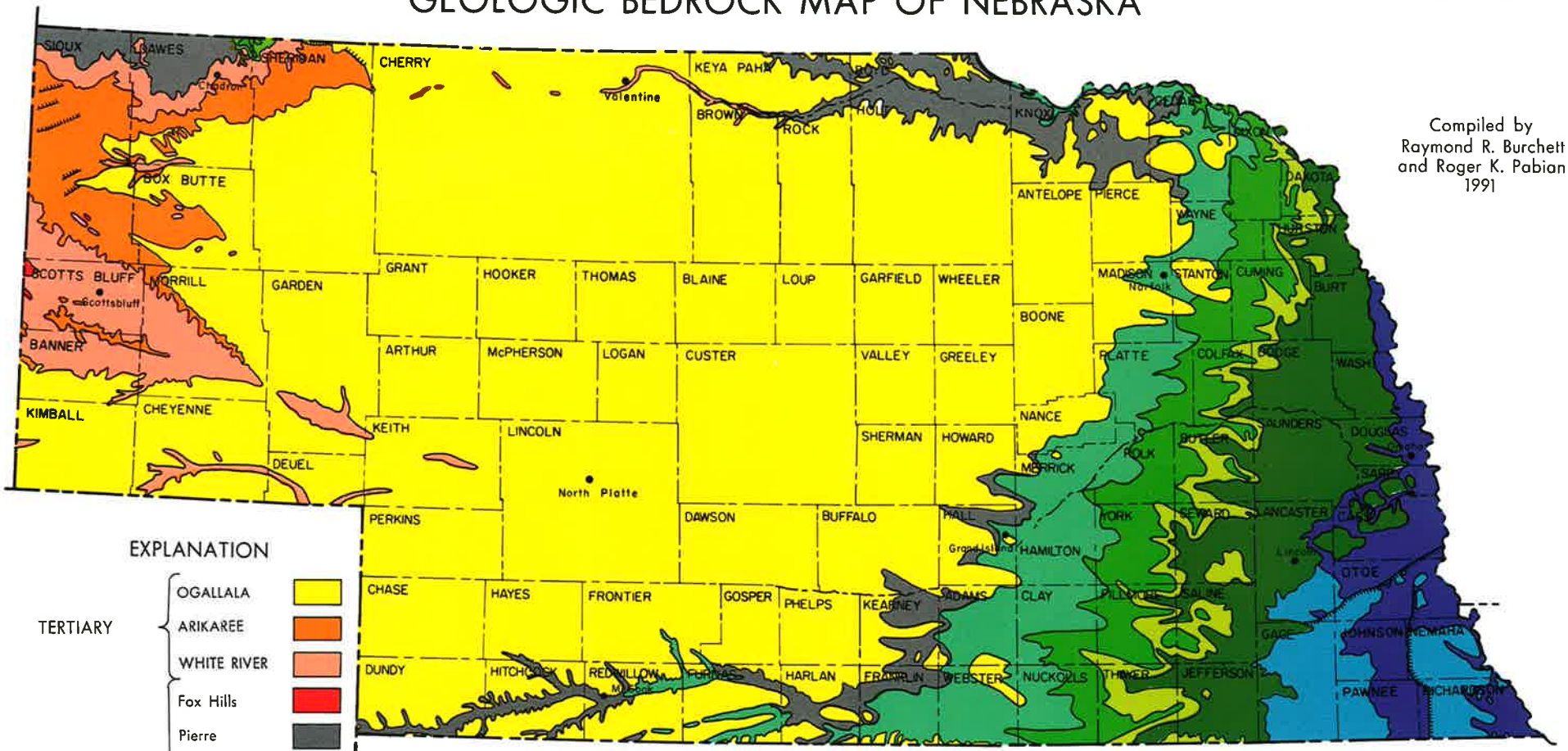
—Postulated Evolution of Platte River and Related Drainages: Souders, V.L., Swinehart, J.B., and Dreeszen, V.H. - Free (GIM-14)

—Native Vegetation Map of Nebraska: Kaul, R.B., and Rolfsmeier, S.B. (1:1,000,000; 1993) - $3.50 (GIM-54)

—Groundwater Vulnerability to Contamination in Nebraska Using the DRASTIC Method: Center for Advanced Land Management Information Technologies; color print (1:1,000,000; 1991) - $2.50 (LUM-31)

Please use order numbers (in parentheses) and add $1.50 for shipping and handling. Nebraska residents should add city and state sales tax.

GEOLOGIC BEDROCK MAP OF NEBRASKA



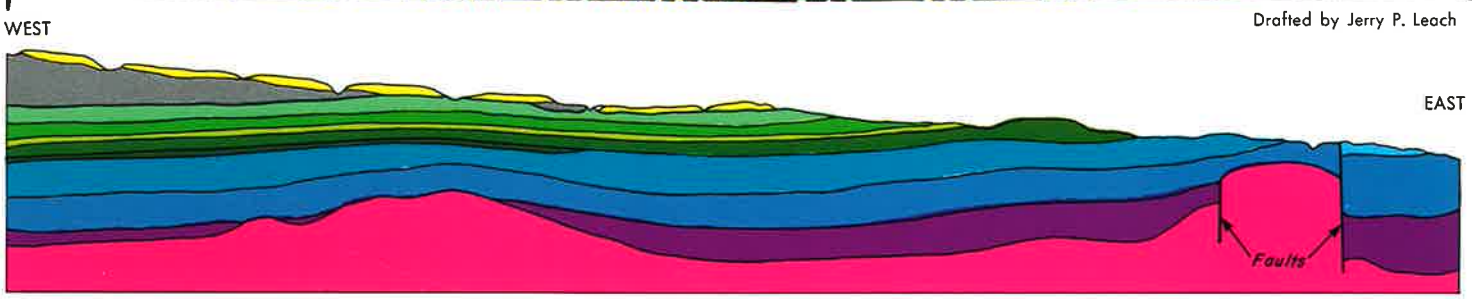
Compiled by
Raymond R. Burchett
and Roger K. Pabian
1991

Drafted by Jerry P. Leach

EXPLANATION

- TERTIARY
  - OGALLALA
  - ARIKAREE
  - WHITE RIVER
- CRETACEOUS
  - Fox Hills
  - Pierre
  - Niobrara
  - Carlile
  - Greenhorn—Graneros
  - DAKOTA
- JURASSIC
- PERMIAN
- PENNSYLVANIAN
- MISSISSIPPIAN
  DEVONIAN
  SILURIAN
  ORDOVICIAN
  CAMBRIAN
- PRECAMBRIAN

Fault



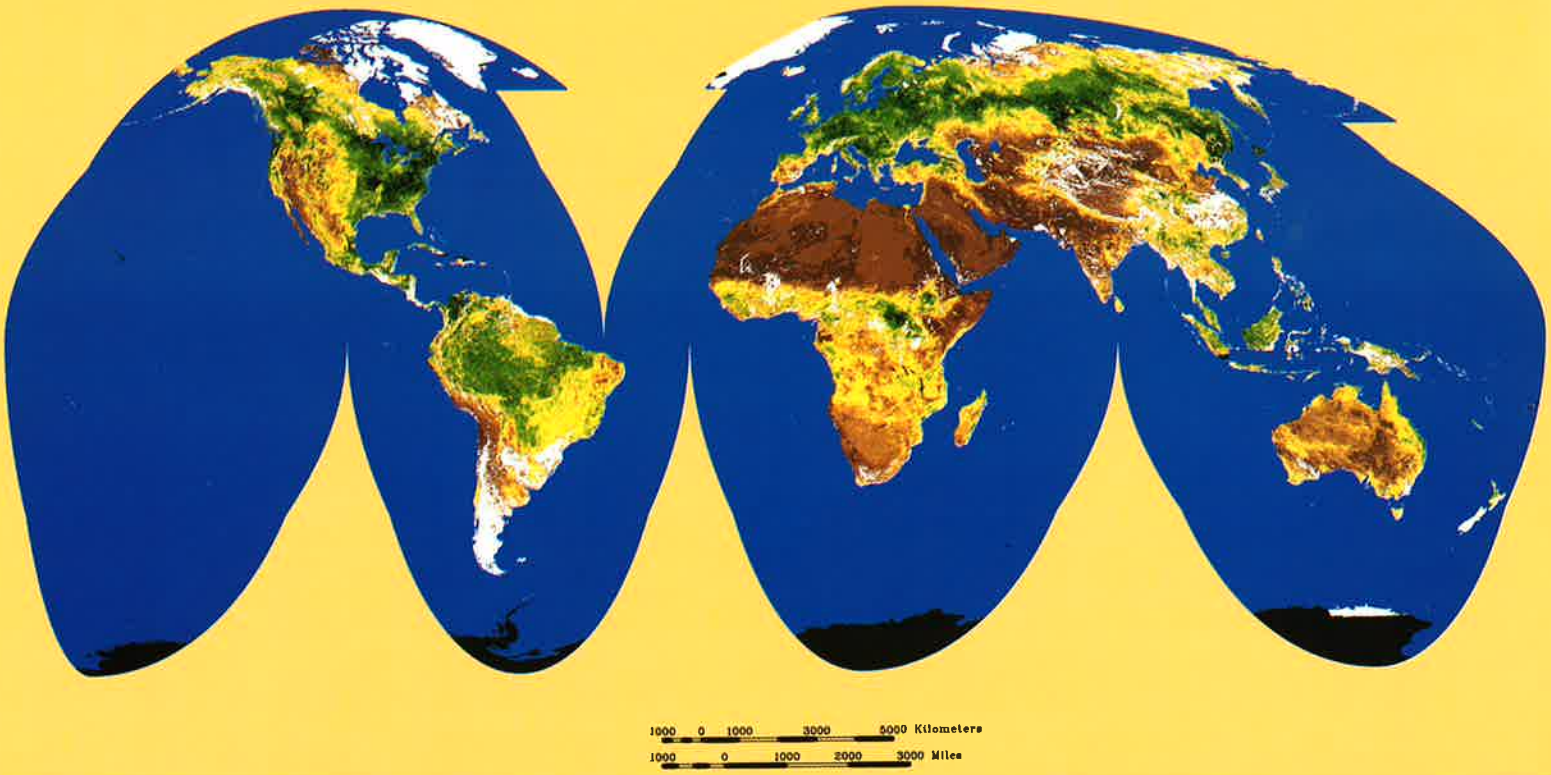
GEOLOGIC CROSS SECTION ALONG SOUTHERN NEBRASKA BORDER

20 0 20 40 60
Scale in Miles

Conservation & Survey Division
Institute of Agriculture and Natural Resources
University of Nebraska—Lincoln

NOTE: Unconsolidated sediments of Recent and Pleistocene age cover the bedrock throughout much of the State and are not shown.

GLOBAL 1-KM AVHRR GREENNESS - 6/21 - 6/30/1992



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